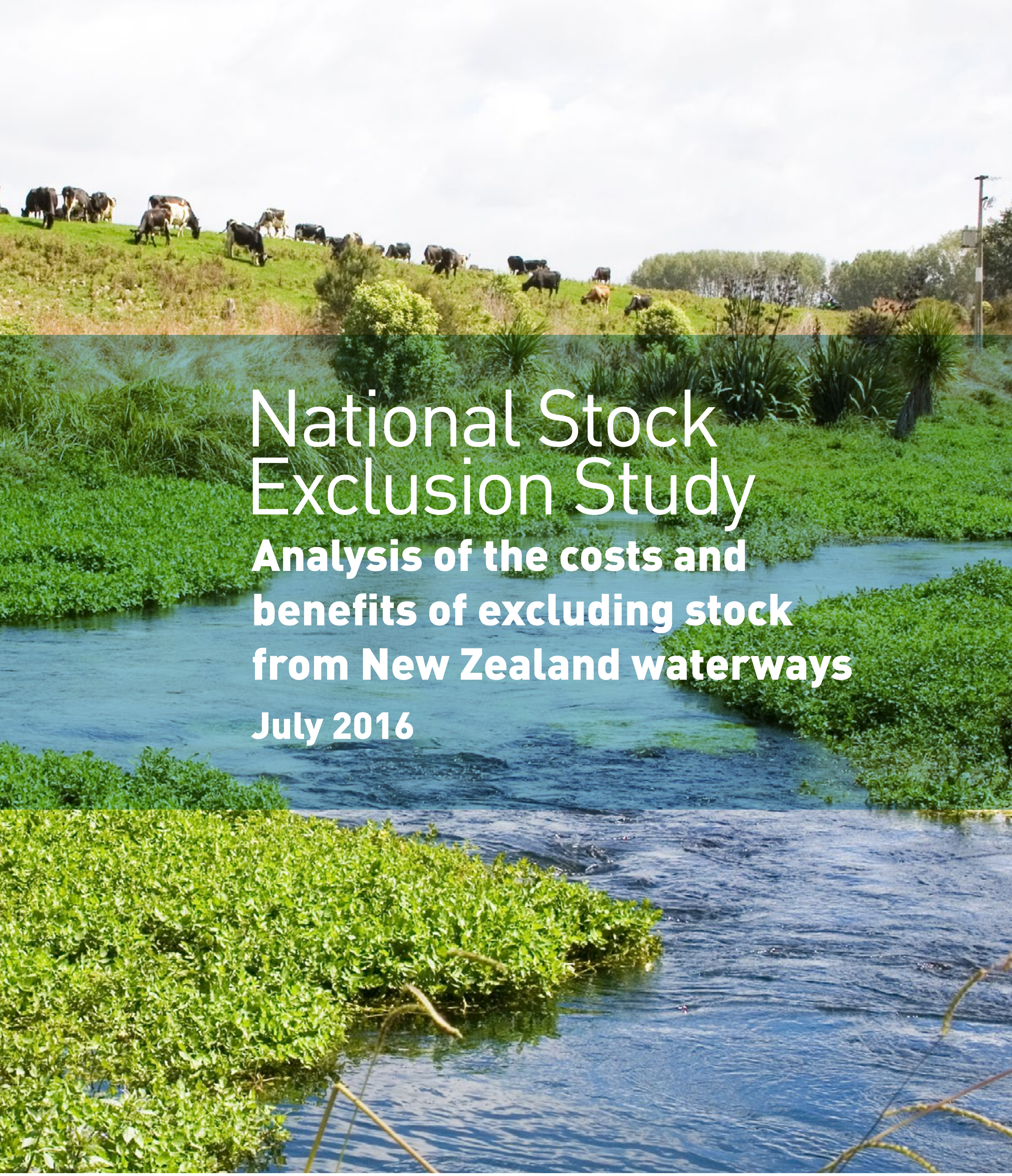

National Stock Exclusion Study

Analysis of the costs and benefits of excluding stock from New Zealand waterways

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Foreword

Since 2009, the Government has been undertaking a comprehensive set of reforms to improve the way we manage fresh water in New Zealand. The reforms emphasise that local communities, through councils, are in the best position to make decisions about managing the fresh water in their region, taking local conditions, needs and aspirations into account.

In 2011, the Government implemented the National Policy Statement for Freshwater Management. The National Policy Statement provides national direction under the Resource Management Act 1991. It requires councils to set objectives and limits for fresh water quality and quantity in a way that is consistent around the country. The National Policy Statement also requires councils to ensure land use and water are managed in an integrated way, and that iwi/hapū are involved in freshwater management and their values are reflected in decisions about the management of fresh water.

Policy development is now focusing on the implementation of the National Policy Statement. This includes providing better information, tools and processes to support communities to make decisions with their councils about their local rivers and waterways. The aim is to increase the value from more efficient use of freshwater, improve freshwater quality and ecosystem health, and ensure economic growth is based on good environmental practice.

To assist with this, the Ministry for Primary Industries and Ministry for the Environment have undertaken several environmental economic studies to build a strong evidence base to support decisions by central government, local government and community stakeholders. These studies demonstrate the link between environmental investment decisions and impacts, help to identify the most appropriate solutions for catchments to achieve particular objectives, challenge assumptions about the likely benefits of different approaches, and help to better target policies.

This paper provides a cost-benefit analysis of different options for excluding stock from freshwater bodies in New Zealand.

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Executive Summary

Excluding stock from waterways stops them from depositing waste in the water and protects the biodiversity of New Zealand's waterways. It also reduces the chances of people getting sick from contact with harmful pathogens often present in animal waste.

In the recent consultation document, *Next Steps for Fresh Water* (Ministry for the Environment, 2016), the Government has proposed a set of national regulations to exclude stock from freshwater bodies in New Zealand. These proposals build on recommendations made by the Land and Water Forum (Land and Water Forum, 2015). To help with the development of regulations, the Ministry for Primary Industries (MPI) has completed a national-scale stock exclusion study in partnership with the Ministry for the Environment (MfE) to estimate the costs and benefits of excluding dairy cattle, beef cattle and deer from waterways.

A significant proportion of New Zealand's waterways that could potentially be affected by stock access have been fenced already. To date, 67 000 kilometres of "Accord waterways" (those wider than 1 metre and deeper than 30 centimetres and permanently flowing) have been fenced.[1]

Existing and proposed requirements set out by regional councils will result in an additional 18 000 kilometres of fencing to exclude more stock by July 2017. This will mean that most dairy cattle will already be excluded by 2017, and only 1379 kilometres of additional fencing would be required to effectively bar all dairy cattle (on milking platforms, and grazing on land owned by both dairy farmers and third parties) from Accord waterways. Farmers would bear most of the stock exclusion costs, while the benefits would be received by all water users in New Zealand.

The Government is proposing to exclude stock on flat and rolling land (less than 15 degrees slope), due to the practicalities of fencing on steep hill country and the high costs relative to the environmental benefits. Regional councils could still apply more stringent rules, where desirable. This study assesses the costs and benefits of excluding dairy and beef cattle, and deer from Accord waterways on flat and rolling land, and the costs and benefits of excluding all stock from Accord and non-Accord waterways up into the hill country.

The study involved five main components:

- identifying the stock exclusion policy options to be analysed;
- estimating the cost of fencing and stock water reticulation (completed by AgriBusiness Group);
- determining the impact of different stock exclusion options on *Escherichia coli (E. coli)* loads in streams, rivers and lakes across New Zealand (completed by the National Institute of Water and Atmospheric Research (NIWA) and AgResearch);
- assessing New Zealanders' willingness to pay for improvements in freshwater quality and estimating the monetary value of reducing *E. coli* loads in water (completed by the Agribusiness and Economics Research Unit at Lincoln University); and finally
- comparing the costs and benefits to identify the most cost-effective stock exclusion option (completed by MPI).

Data were gathered from various sources including:

- water quality improvement preferences from a survey of 2032 New Zealand residents;
- the *2015 Survey of Rural Decision Makers* (Landcare Research);
- the FarmsOnline geospatial database (MPI);
- the 2015 Agricultural Production Survey and 2013 Population Census (Statistics New Zealand);
- Land, Air, Water Aotearoa water quality data.[2]

Fencing costs were based primarily on direct quotes from fencing contractors from 16 regions and published sources such as the Lincoln University Financial Budget Manual (Lincoln University, 2014). Labour and material costs and the costs of stock water reticulation were quantified by region.

Econometric and environmental models were used to determine New Zealanders' willingness to pay to

1 Accord waterways have been defined in the Sustainable Dairying – Water Accord (DairyNZ, 2013).

2 https://www.lawa.org.nz/

achieve improvements in freshwater quality. It was found that people place great value on improvements in water clarity and ecosystem health. It was not possible, however, to obtain suitable estimates of the effect of stock exclusion on attributes such as water clarity and sediment concentration. Benefits were quantified in terms of reduced risk to human health from lower *E. coli* loads in fresh water.

The impacts of stock exclusion on reducing *E. coli* loads to fresh water were examined in the context of changes in the proportion of waterways that meet the different states required for human health for recreation, as outlined in the National Objectives Framework within the *National Policy Statement for Freshwater Management (NPS-FM)* (Ministry for the Environment, 2014).[3] For example, excluding all dairy and beef cattle and deer from Accord waterways would result in an additional 1997 kilometres of stream length meeting the minimal acceptable state for primary contact recreation (for activities such as swimming). An additional 6100 kilometres of Accord waterways would move into the "A Band" of the National Objectives Framework for secondary contact recreation (activities such as wading and boating).[4]

An *E. coli* Contaminant Load Model was developed by Semadeni-Davies and Elliott (2016) at NIWA to determine changes in *E. coli* loads in fresh water from fencing. The model produced valid results, especially given the difficulty and uncertainty associated with estimating *E. coli* loads. This supports the overall reliability of the national study and provides confidence that the costs and benefits quantified are as accurate as possible given the information currently available.

3 The *National Policy Statement for Freshwater Management* can be found here: http://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/nps-freshwater-management-jul-14.pdf. Refer to page 31 in Appendix 2 for a description of the *E. coli* attribute states.

4 Primary contact recreation is defined as activities involving full immersion in fresh water, such as swimming. Secondary contact recreation is defined as activities likely to involve occasional immersion in, and some ingestion of, fresh water, such as wading and boating.

Cost–benefit analysis results

The costs and benefits of different stock exclusion policy options were calculated and compared, to assess which options would result in the highest net benefit (the greatest benefit from an increase in the proportion of waterbodies with a low human health risk relative to the expenditure on fencing and associated stock water reticulation). Costs and benefits are presented in Table 1 and are discounted at 8 percent over a 25-year period.

Overall, the results suggest the greatest return on investment will be achieved by fencing off Accord streams on all dairy farms and land where dairy cattle are grazed, before 2025, with a return for all New Zealanders of $8.10 for every dollar spent on fencing.

To fence dairy cattle on milking platforms would cost $20 million and result in benefits of $65 million. If stock exclusion is extended to all dairy cattle grazing on other land (for example, run-offs) owned by dairy farmers, costs would increase by $1.4 million with additional benefits of $68 million. Including all dairy cattle grazing on land owned by a third party increases costs by $10 million and benefits by $125 million.

Combining these options, excluding all dairy cattle from Accord waterways results in total costs of $32 million and benefits of $258 million over and above current fencing levels. This results in net benefits of $226 million.

The costs of excluding all dairy cattle are comparatively lower than for other land uses such as beef cattle and deer, because 99 percent of dairy farms have already fenced off some of their Accord waterways (Brown, 2015).

To exclude beef cattle from Accord waterways, farmers would need to fence 16 860 kilometres of waterways by 2030, at an additional cost of

Table 1: Present value of costs and benefits of stock exclusion policy options (over a 25 year period, discounted at 8 percent)

Option	Policy scenarios – stock to be excluded	Marginal costs and benefits of excluding additional stock types from waterways			Cumulative costs and benefits of stock exclusion scenarios			
		Additional cost NZ$m	Additional benefits NZ$m	Net marginal benefits NZ$m	Total cost NZ$m	Total benefits NZ$m	Total net benefits NZ$m	Benefit–cost ratio
1	Baseline: Current fencing, including regional council requirements, to be implemented by July 2017	N/A	N/A	N/A	7 875	864	–7 011	0.1
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	20	65	45	20	65	45	3.2
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	1	68	67	22	133	112	6.2
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	10	125	114	32	258	226	8.1
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	327	716	390	358	974	616	2.7
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	9	10	0.95	367	983	617	2.7
7	ALL Exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	1 069	2 386	1 317	1 436	3 370	1 934	2.3

$327 million. The benefit, calculated as the amount New Zealanders would be willing to pay to achieve the reduction in human health risk likely to be realised from fencing off beef cattle from waterways, was $716 million, resulting in net benefits of $390 million.

Fencing to exclude deer from Accord waterways returns a net benefit of $954 000. The total additional costs of fencing deer are not as great as fencing beef cattle (an additional $8.5 million) because fewer streams need to be fenced (only 260 kilometres compared with 16 860 kilometres). Deer fencing, however, is the most expensive type of fencing, at around $18 per metre.

Excluding all dairy and beef cattle and deer from Accord waterways on flat and rolling land is estimated to produce net benefits of $617 million (costs of $367 million and benefits of $983 million over 25 years).

Extending the requirement for fencing cattle and deer out of Accord and non-Accord waterways into the hill country increases the cost by over $1 billion. The total costs of fencing all dairy and beef cattle and deer from Accord and non-Accord streams on flat and rolling land and hill country (slopes less than 28 degrees) is significant, at $1.4 billion. However, the benefits are even greater at $3.4 billion, resulting in net benefits of $1.9 billion. This would result in over 70 000 kilometres of new fencing.

A big driver of the costs of fencing beef cattle and deer from waterways is the cost of stock water reticulation. It is not known how many waterways are currently used by stock as drinking water. In many cases, alternative water supplies may already be available, which would reduce the costs of excluding stock from waterways. Further work is needed to quantify the extent of reticulation required. The costs of riparian planting have also not been quantified, because of the variability that exists across the country.

The study did not quantify the benefits that would be gained from improvements in ecological quality and water clarity as a direct result of fencing to exclude stock (for example, as a result of lower stream bank erosion and sedimentation). As these benefits were more highly valued by survey respondents, the estimates of benefits presented in this report are conservative and would likely be much higher if the improvements to water clarity and ecological quality were also considered.

1 Introduction

Public awareness of the need to protect New Zealand's waterways and improve the quality of rivers, lakes, streams and wetlands is growing.

One area of concern is the damage caused by livestock incursions into waterways. Animals may also deposit urine and faeces on surrounding stream banks. Heavy rain and rising water levels can flush this waste into streams. Damage results from direct contamination of waterways and the effects on local habitat quality. In freshwater areas, stock activity around and within waterways:

» can damage eel grass beds, which are a natural habitat and breeding ground for native fish;

» can spread weeds;

» adds sediment and phosphorous from pugging and bank erosion, which reduces water clarity and increases algal blooms; and

» can negatively affect the aquaculture industry and other downstream water users (both animal and human) who rely on clean water to drink.

Keeping stock out of waterbodies stops cattle from urinating and defecating in waterways and protects the biodiversity of the water through improved in-stream habitats and reduced damage to riparian plants. Having an ungrazed margin along the banks of a waterway has the ability to filter contaminants, such as sediment and effluent, from paddock run-off before it flows into the water. Removing stock from stream banks also helps to maintain the integrity of banks and reduces sediment and other pollutants from being pushed into the water.

In addition to reducing contaminants from entering waterways, stock exclusion can prevent significant damage to local habitats and potentially improve other physio-chemical parameters of water quality (for example, temperature and dissolved oxygen).

Fencing off waterways has a number of stock management advantages, including improvements in animal health, such as reduced risk of liver fluke, better oversight of stock (because they are not hidden from view down stream banks or in scrub), reduced likelihood of stock being stuck in waterways and young stock drowning, and more efficient movement of stock and use of pasture, often through the use of temporary electric fencing.

Fencing to exclude stock from waterways can also have adverse impacts on the farm system, its management and the surrounding environment, so careful design is needed in flood-prone areas. Stock exclusion can aid prolific weed growth causing seed transfer and fire risk and may add to farm infrastructure costs, for example, from realigning existing fence lines, adding culverts and installing a water reticulation system.

1.1 New Zealand's waterbodies

New Zealand has over 400 000 kilometres of rivers and streams and around 4000 lakes. The longest river is the Waikato, with a length of 425 kilometres, and the largest river by volume is the Clutha, with a mean discharge of 533 cubic metres per second. Nearly 168 600 kilometres of waterways are potentially accessible to stock.

A river is defined in section 2 of the Resource Management Act 1991 as a continually or intermittently flowing body of fresh water. It includes a stream and modified watercourse but does not include any artificial watercourse (including an irrigation canal, water supply race, canal for the supply of water for electricity power generation and farm drainage canal).

Streams and rivers in New Zealand are classified using the River Environment Classification (Version 2) (REC2) database. This contains stream length, the reach sub-catchment area, size of the stream, estimated mean annual flow rate and average slope.

In 2003, the Dairying and Clean Streams Accord was signed between the then Ministry of Agriculture and Forestry, MfE, Fonterra and Local Government New Zealand (on behalf of the regional councils). The aim of the Accord was to have 90 percent of dairy cattle excluded from Accord-type waterways by 2012.

In 2013, the Accord was succeeded by the Sustainable Dairying Water Accord, which outlines several commitments from the dairy industry in relation to fresh water, building on the earlier Accord. The Accord comprises a set of commitments by the industry body DairyNZ, the Dairy Companies Association of New Zealand and individual dairy companies.

Based on these commitments, waterways have been defined in New Zealand as either Accord or non-Accord streams. Accord streams are defined as deeper than a gumboot (deeper than 30 centimetres) and wider than a stride (wider than 1 metre) and permanently flowing. There are 93 216 kilometres of non-Accord waterways (23 percent of waterways) and 306 874 kilometres of Accord waterways (77 percent) in New Zealand. Appendix 1 shows the lengths of non-Accord and Accord streams by slope class and region. As discussed in Section 2.1, according to the *2015 Survey of Rural Decision Makers,* 99 percent of dairy farms have some Accord streams fenced as of 2015.

1.2 National Policy Statement for Freshwater Management

The importance of freshwater quality to New Zealand's economic, environmental, cultural and social well-being has been established in the National Policy Statement for Freshwater Management (NPS-FM) (Ministry for the Environment, 2014). The NPS-FM recognises the national significance of water and directs regional councils to set objectives for the state that their communities want for their waterbodies in the future and to set limits to meet these objectives.

The NPS-FM includes a National Objectives Framework (NOF) that guides regional councils in their objective setting at a local level. This involves:

- identifying all the values held by tangata whenua and the community on freshwater management units;
- identifying attributes (the measurable characteristics) that need to be managed to provide for those values; and
- formulating freshwater objectives (based on those attributes) that describe the outcome a regional council wants to achieve (Ministry for the Environment, 2014).

1.3 *E. coli* as an indicator of freshwater contamination

In this study, *E. coli* was used as an indicator of risk to human health from contact with fresh water in New Zealand. *E. coli* is a type of bacteria that normally lives in the intestines of people and animals. Most *E. coli* are harmless and are actually an important part of a healthy human intestinal tract. However, some *E. coli* are pathogenic, meaning they can cause illness such as diarrhoea or illness outside of the intestinal tract. The types of *E. coli* that can cause diarrhoea can be transmitted through contaminated water or food or through contact with animals or people.

E. coli is used as an indicator of freshwater faecal contamination as part of risk assessments of pathogen infection and is one of the attributes of the "human health" water quality value in the NOF. Managing fresh water to this value is compulsory under the NOF, and the *E. coli* attribute is assessed against annual median and 95th percentile concentrations of *E. coli* in fresh water. The NOF makes the assumption that if *E. coli* is present in freshwater bodies then other more pathogenic faecal micro-organisms are also likely to be present.

In general, higher levels of *E. coli* would indicate an increasing risk of infection in humans who use fresh water for primary and secondary contact recreation activities. The NOF bottom line for secondary contact recreation (for example, kayaking and wading) is an annual median concentration of 1000 colony forming units per 100 millilitres, while the minimum acceptable state for full immersion is a 95th percentile concentration of less than 540 colony forming units per 100 millilitres. Figure 1 provides a representation of the NOF bands in terms of risk to human health. Appendix 2 provides technical definitions of the NOF bands.

The main source of faecal contamination in rural freshwater bodies is grazing livestock, although water fowl and other wild or feral animals can be additional sources. *E. coli* from stock enters the stream network via direct deposition of faecal matter into the stream or via indirect pathways including discharges of dairy effluent into streams, surface wash-off in areas of steep terrain, overland flow from excess irrigation water and drainage via artificial drains (Collins et al, 2007; Muirhead, 2015).

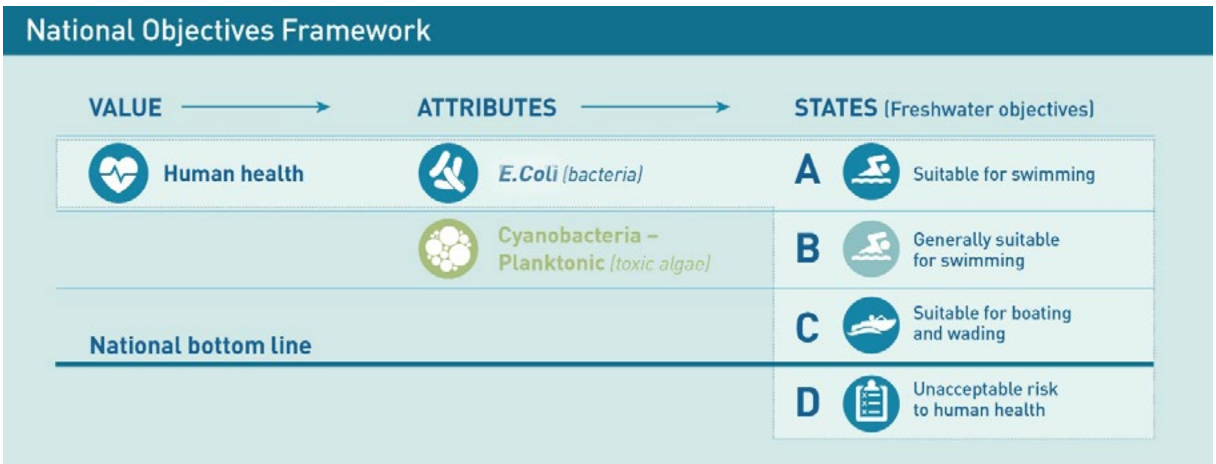
Current state of waterbodies in New Zealand

Table 2 shows the proportion of Accord and non-Accord waterways in the A and B bands for primary contact recreation (based on 95th percentile measurements). Table 3 shows the proportion of Accord and non-Accord waterways in each NOF band for secondary contact recreation (based on annual median measurements). The results are shown for the northern North Island (Northland, Auckland, Waikato, Bay of Plenty, Gisborne), southern North Island (Taranaki, Manawatū–Whanganui, Hawke's Bay, Wellington) and the South Island.

Forty-eight percent of Accord waterways are in the A Band for primary contact recreation and 9 percent are in the B Band, indicating that 57 percent of Accord waterways meet the requirements for primary contact recreation in terms of *E. coli* levels. Most of the Accord waterways in the A Band are in the South Island.

Ninety-one percent of Accord waterways are in the A Band for secondary contact recreation and

Figure 1: National Objectives Framework – Attributes for human health



Source: MfE, 2014

8 percent are in the B Band. Overall, 100 percent of Accord waterways meet the national bottom line for secondary contact recreation.

1.4 Government proposal to exclude dairy, beef and deer from waterways

The Government has publically signalled its intention to introduce a national regulation to exclude dairy cattle (on milking platforms) from waterways by July 2017. As part of this process, the Government sought public submissions on the design of stock exclusion regulations through the *Next Steps for Fresh Water* consultation document (Ministry for the Environment, 2016).

The Government is considering extending the requirement to exclude dairy cattle (on dairy support), beef cattle and deer from waterbodies at a later date, to give farmers time to comply. Sheep and goats are not included in the Government's proposal because they do less damage to streams and rivers.

The Government is only proposing to exclude stock on flat and rolling land (less than 15 degrees slope), due to the practicalities of fencing on steep hill country and the high costs relative to the environmental benefits. Regional councils could still apply more stringent rules, where desirable.

1.5 Purpose of this study

This study estimates the costs and benefits of excluding dairy cattle, beef cattle and deer from New Zealand waterways to determine the net benefits of different stock exclusion options. Benefits are assessed in terms of New Zealanders' willingness to pay for reduced risks to human health from a reduction in *E. coli* concentrations in streams, rivers and lakes. Costs are assessed in terms of the costs of erecting permanent or temporary fencing and installing stock water reticulation systems.

As shown in Figure 2, the study includes five main components:

» identifying the stock exclusion policy options to be analysed;

» estimating the cost of fencing and stock water reticulation;

» determining the impact of different stock exclusion options on *E. coli* loads in streams, rivers and lakes across New Zealand;

Table 2: Proportion of Accord and non-Accord waterways in each National Objective Framework *E. coli* band (95th percentile concentration) for primary contact recreation by super region, based on current fencing levels and regional council requirements

	Accord waterways			Non-Accord waterways		
Super region	A Band (%)	B Band (%)	Below minimal acceptable state (%)	A Band (%)	B Band (%)	Below minimal acceptable state (%)
Northern North Island	26.0	8.9	65.0	14.0	7.0	79
Southern North Island	28.7	9.7	61.6	16.2	10.3	73.5
South Island	64.5	9.5	26.0	42.2	8.7	49.0
Total	48.0	9.0	43.0	30.0	9.0	62.0

Table 3: Proportion of Accord and non-Accord waterways in each National Objective Framework *E. coli* band (annual median concentration) for secondary contact recreation by super region, based on current fencing levels and regional council requirements

	Accord waterways				Non-Accord waterways			
Super region	A Band (%)	B Band (%)	C Band (%)	Below acceptable state (%)	A Band (%)	B Band (%)	C Band (%)	Below acceptable state (%)
Northern North Island	83.5	15.6	0.8	0.0	74.7	24.4	0.9	0.0
Southern North Island	93.3	6.6	0.0	0.0	85.4	14.6	0.0	0.0
South Island	94.1	5.9	0.0	0.0	85.2	14.8	0.0	0.0
Total	91.4	8.4	0.2	0.0	83.0	17.0	0.0	0.0

» assessing New Zealanders' willingness to pay for improvements in freshwater quality and estimating the monetary value of reducing *E. coli* loads in water; and finally

» comparing the costs and benefits to identify the most cost-effective stock exclusion option.

The analysis was undertaken at a regional and national scale. National-scale analysis was required because the study is intended to inform decisions about a potential national regulation for stock exclusion. However, it was also recognised that a study of this nature would have significant value for regional authorities as well.

1.6 Stock exclusion options

The stock exclusion options being considered at the time by the Land and Water Forum (LAWF) formed the basis of the analysis (Land and Water Forum, 2015a). A counterfactual or baseline was established to compare the effect of the stock exclusion options. The baseline included the current level of stock exclusion and regional council stock exclusion requirements that will be in effect by 2017.

The stock exclusion policy options generally followed those being recommended by the LAWF, with the exception of pigs. Pigs were not analysed in the scenarios because they are usually housed in New Zealand, and where they are housed they will be excluded from waterways.[5] The LAWF did not recommend sheep be required to be excluded because they are known to be reluctant to enter waterways. This approach was also adopted for this study. An additional policy option was added that excluded all cattle (dairy and beef) and deer into hill country (up to 28 degrees slope).

5 Nearly 91 percent of pigs commercially farmed in New Zealand are housed (for example, kept in indoor or outdoor pens, not free range), according to records within the Agricultural Greenhouse Gas Inventory Model administered by MPI.

Figure 2: Components of the national stock exclusion study

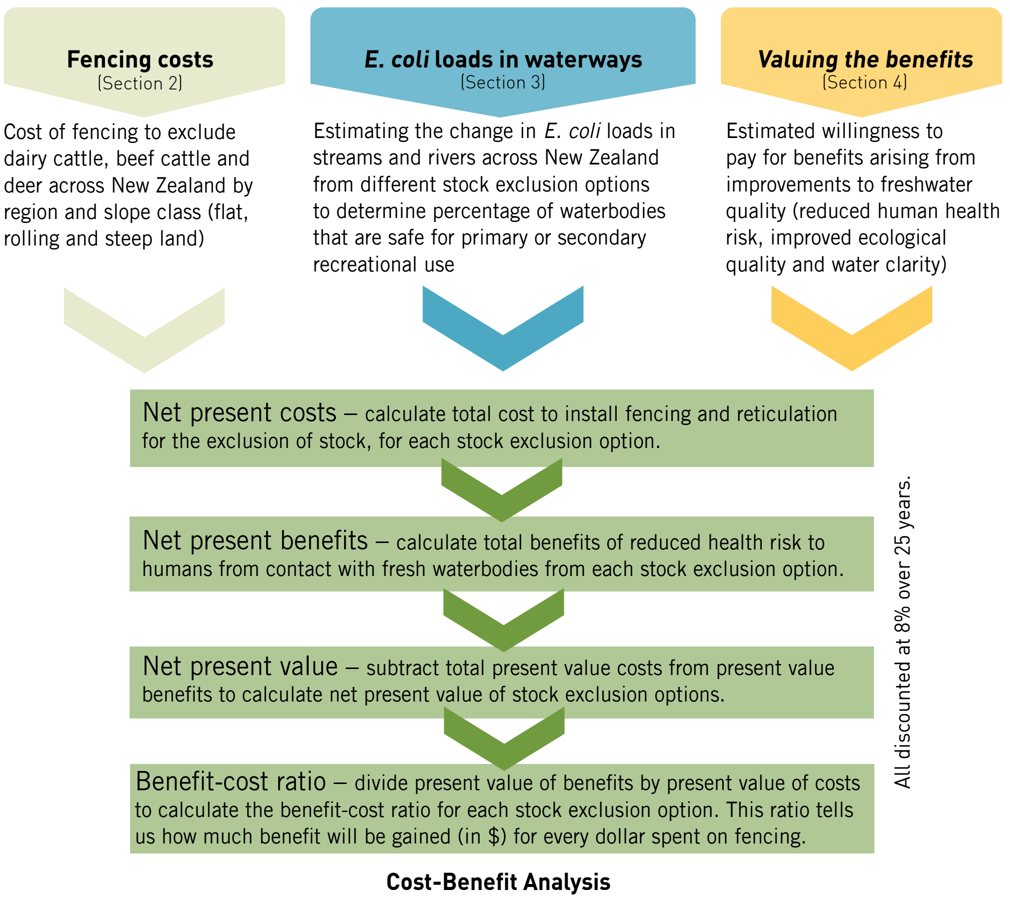


Table 4 summarises the stock exclusion options assessed in the analysis.

Appendix 3 provides further detail about the stock exclusion policy options, the information needed to model the different options and the assumptions applied.

1.7 Outline of the paper

Section 2 outlines the methodology used to determine the costs of different types of fencing on different terrains and for different land uses. Cost estimates are presented for the different stock exclusion policy options. Section 3 discusses the methodology used for estimating changes in *E. coli* loads from excluding stock and provides data on the likely changes in *E. coli* loads.

Section 4 sets out the methodology used to determine the main values associated with freshwater bodies in New Zealand and New Zealanders' willingness to pay for improvements in freshwater quality. By using this information, it is possible to estimate the benefits of stock exclusion in monetary terms. Section 5 compares the costs and benefits to determine the most cost-effective stock exclusion policy option. Section 6 provides a discussion of the main findings.

Table 4: Stock exclusion policy options

Option	Stock exclusion policy options	
1	Baseline	Current level of fencing to exclude stock, plus further fencing in regions that either have a fencing policy or are planning to have new fencing policies in place by 2017.
For options 2 to 6, fencing is along Accord waterways with an average slope of less than 16 degrees (flat and rolling), with the fencing successively excluding different stock as follows:		
2	Baseline plus:	All dairy cattle on dairy platforms (that is, milking herd) by 2017.
3	Option 2 plus:	All dairy cattle grazing on run-offs owned or leased by dairy farmers by 2020.
4	Option 3 plus:	All dairy cattle grazing on run-offs owned by a third party by 2025.
5	Option 4 plus:	All beef cattle excluded by 2025 on flat land, and 2030 on rolling land.
6	Option 5 plus:	All deer excluded by 2025 on flat land, and 2030 on rolling land.
7	Option 6 plus, non-Accord and Accord waterways into steep country	Fencing along all streams, both Accord and non-Accord, accessible to all dairy, beef and deer stock, on land with an average slope of less than 28 degrees by 2017.

2 Fencing of stock

Fencing of waterways is one component of a suite of options available to enhance freshwater quality and is effective at keeping stock out of water. This section describes the costs associated with erecting fences and installing stock water reticulation systems to exclude various types of stock from freshwater bodies in New Zealand. It is important to understand the different types of fencing required to exclude dairy, beef and deer stock on various terrains and the costs likely to be incurred.

MPI commissioned the AgriBusiness Group to provide information on the costs of fencing, reticulation and riparian planting (Lucock, 2016). The types and costs of fencing used to exclude stock from waterways in different regions of New Zealand were identified and categorised through discussions with MPI and informal consultation with regional council staff.

2.1 Current state of fencing in New Zealand

To date, most fencing around waterways has been on flat and rolling country. The 2015 *Survey of Rural Decision Makers* provides information on the extent of fencing across New Zealand (Brown, 2015). Table 5 shows the current level of fencing by enterprise type.

Around 67 000 kilometres of Accord waterways have been fenced as of 2015. Existing and proposed requirements set out by regional councils will result in an additional 18 000 kilometres of Accord waterways being fenced to exclude more stock by July 2017. These changes would occur in Auckland, Taranaki, Hawke's Bay, Wellington, Marlborough and Canterbury.

Only 1379 kilometres of additional fencing would be required to exclude all dairy cattle (on dairy platforms, and cattle grazing on land owned by either dairy farmers or third parties). To exclude beef cattle from waterways on flat or rolling land, farmers would need to fence an additional 16 860 kilometres of waterways. To fence all deer farms on flat or rolling land would require an additional 260 kilometres of fencing along waterways.

A review of regional council activity by the LAWF found that stock access to waterways is generally permitted across the country except in areas prone to bank or bed erosion, or when minimum standards for suspended soils and/or turbidity or clarity are not being met (Land and Water Forum, 2015b). Regions that either already have specific stock exclusion policies in place or are planning changes in policy are listed in Appendix 4. While similarities might occur in waterways and their management across different regions, fencing, riparian planting type and riparian management are not prescriptive within or across regions, because of the uniqueness of individual waterways and their surroundings.

Regional councils offer various resources and funding opportunities for land managers to enhance their unique environment, including help with excluding stock from waterways. A range of riparian planting programmes and initiatives also influence the degree of fencing of waterways and management of riparian margins (including the development of budgeting resources, good management practices on farms and guidelines). Such initiatives include the Sustainable Dairying: Water Accord (DairyNZ, 2013) and the "Million Metres Streams Project", which was set up to restore the health of New Zealand waterways. (The "Million Metres Streams Project" is helping New Zealanders raise money to undertake large-scale tree planting along waterways through the use of crowdfunding. The goal is to collectively fund a million metres of tree planting along stream banks across New Zealand).

2.2 Types of fencing required to exclude stock

A fence needs to be designed to suit the particular stock type, as well as the climate and terrain. Box 1 outlines the different types of fences available and when they should be used.

Table 5: Current level of fencing of Accord waterways by enterprise type

Enterprise type	Number of respondents	Percentage of farms with fencing (%)[1]	Mean percentage of waterways on farms that are fenced (%)[2]	Estimated current level of fencing (%)
Dairy	503	99.3	94.7	94.0
Sheep and beef	1156	77.4	67.5	52.2
Deer	54	88.9	60.3	53.6
Grazing[3]	136	91.7	75.7	69.5
Other pastoral[4]	56	90.0	85.1	76.6

1 Of streams that meet the Accord definition.
2 Among those that have any fenced streams that meet the Accord definition.
3 Grazing is dairy grazing.
4 Other pastoral includes other pasture users such as pigs and horses.

Source: Brown (2015)

Box 1: Different types of fencing

Non-electric wire
Used commonly for boundary fencing and as a general all-purpose fence. It is strong, durable and secure. Typically 7 or 8 wire posts are usually 4 metres apart, and five battens are spaced evenly between the posts. It is one of the most expensive and labour-intensive fences, but it will contain sheep, cattle and horses.

Multi-wire electric
Different numbers of wires can be used, depending on the type of stock being excluded, which can then be electrified. For example, sheep need more wires to contain them. Posts are spaced further apart, sometimes up to 8 or 10 metres between posts. Because electric fences require fewer materials, they are cheaper, easier and faster to erect; however, they may not be as secure or long lasting. Electric fences create a mental barrier to stock, with the shock acting as a deterrent in future escape efforts.

Netting fences
Constructed with prefabricated netting with one or two strands of wire to support the netting. It is moderate in price. Deer netting is one of the best ways of containing young fawns. Deer are flighty animals that can comfortably leap traditional fences or push between wires that are tightly strained. Deer fences need to be 1.9 metres high and are normally constructed with netting designed specifically for holding deer.

Temporary fencing
Electric plastic tape is usually wound up on a hand reel. It is used mainly for cattle to subdivide an existing paddock. It uses "electric fence standards", which are lightweight and about 1 metre in height.

2.3 Fencing material and labour costs

Discussions and data gathering with regional council staff provided information and budgeted costs of fencing and riparian planting, where this was part of regional council policy and current practice. Eight of the 16 regional councils had some form of fence and riparian cost calculations. They ranged from a web-based public tool (Waikato Regional Council) to spreadsheets available on request (Environment Southland, Bay of Plenty Regional Council) to budget figures that can be discussed with regional council staff. Industry bodies are currently working on several additions to the suite of calculators that are publicly available.

Fencing labour costs were collected through telephone and email surveys of 52 members of the Fencing Contractors Association of New Zealand from all regions across New Zealand. Additional telephone conversations (or emails) were conducted with 12 of the 16 regional councils, staff from the Department of Conservation, Landcare Research, AgResearch, Waihora Ellesmere Trust, Queen Elizabeth II National Trust and Landcare Trust.

Labour costs varied across fencing contractors in different regions and tended to be cheaper in the South Island compared with the North Island. Fencing material costs were gained from fencing merchants nationally (Goldpine; Great Southern; NZ Farm Source; PGG Wrightsons and Farmlands) as well as the Lincoln University Financial Budget Manual (Lincoln University, 2014).

Wooden fencing material (strainer posts, stay posts, posts and battens) costs also differed between the two islands, with these materials being cheaper in the North Island. All other fencing materials were the same price within companies across New Zealand, and the only price differences were found between companies.

Information on labour and material fencing costs was gathered on the basis of the following hypothetical scenario:

» one-kilometre long fence line;
» nine angle assemblies;
» one gateway assembly (at one end of the fence);
» post driver able to be used on flat and rolling terrain, but not steep terrain;
» posts spaced at 4 metres for non-electric and 10 metres for electric fences, where possible.

Table 6 provides the maximum, average and minimum total per metre costs of fencing (labour plus materials) from aggregated data collected from 16 regions across New Zealand. Table 26 in Appendix 5 shows the labour cost of fencing for the five different fence types over three terrains (flat, rolling and steep). Labour costs for fencing rolling country were similar to those for flat country. Steep country labour costs (where holes were hand dug) averaged 134 percent of the cost of fencing on the rolling country.

Table 27 in Appendix 5 shows the fencing material costs of the five fence types in the different regions of New Zealand. Topography does not influence the cost of fencing materials but does influence labour costs. Table 28 in Appendix 5 combines the labour and material fencing costs to show the total cost per metre for five fence types over flat, rolling and steep topography in the different regions of New Zealand.

Total fencing costs incorporate the following parameters per metre:

» the cost of fencing materials, for both permanent and temporary fencing;
» the labour cost of installation, for both permanent and temporary fencing;
» maintenance costs at 1 percent of total material costs for permanent fencing. This was increased to 2 percent on steep land, because fences on steep land are known to be subject to more environmental damage (wind, erosion) and damage by animals than fencing on flat or rolling land;
» cost of supplying an alternative stock drinking water source via reticulation.

Overall, deer fencing is the most expensive to install compared with other types of fencing. Electric 2-wire fencing is the cheapest option. Generally, labour costs were the most expensive in Auckland and considerably lower in Canterbury and Southland. Material costs for the cheapest type of fencing on flat land (electric 2-wire fencing to exclude cattle) were the cheapest in Southland and the most expensive in the Greater Wellington region.

In some instances, temporary fencing was determined to be the most practical, rather than permanent fencing. Electric fences have been used in New Zealand agriculture for over 50 years and have, in many cases, been a more affordable option (in regard to capital costs) than the non-electric fencing alternatives. It is relatively easy for farmers to better use pasture through temporary fencing (also called break or strip fencing). These fence types are, however, often not stock proof if power is reduced due to earthing of the live wire. Stock grazing tends to keep vegetation from earthing the live wires when these fences are used as internal fences (stock can graze both sides).

Little documented information is available to inform the development of temporary fencing estimates.

Temporary fencing estimates were based on advice provided by the AgriBusiness Group. Assumptions had to be made about the labour and material costs of temporary fencing. It was estimated it would take an hour to put up a temporary fence at a labour cost of $30 per hour. Material costs included a geared reel with 500 metres of polywire at a cost of $105 and 100 electric fence standards at $5 each. Overall, this equated to a cost of temporary fencing of $1.27 per metre as shown in Table 7.

Table 6: Maximum, average and minimum total per metre fence costs (NZ$) for five fence types over flat, rolling and steep topography

Stock type	Fence type	Topography	Max (NZ$)	Ave (NZ$)	Min (NZ$)
Sheep/cattle	Non-electric 8 wire	Flat	16.36	13.02	9.90
		Rolling	17.88	13.66	10.38
		Steep	24.88	16.64	12.06
	Non-electric netting	Flat	15.81	11.99	8.82
		Rolling	18.83	12.63	8.82
		Steep	26.81	16.01	10.32
Deer	Non-electric netting boundary fence	Flat	28.90	18.90	13.70
		Rolling	28.90	19.68	14.20
		Steep	32.55	22.71	15.70
Sheep/cattle	Electric 4 wire	Flat	11.21	6.56	4.40
		Rolling	12.21	6.88	4.40
		Steep	13.21	8.25	4.90
Cattle	Electric 2 wire	Flat	8.58	4.67	2.91
		Rolling	10.58	4.89	3.21
		Steep	11.58	5.94	3.66

Table 7: Estimated costs of temporary fencing used to exclude stock

Item for 500 metres of fence	Quantity	Cost per item (NZ$)	Total cost for 500 metres of temporary fencing (NZ$)	Total cost per metre (NZ$)
Geared reel	1	105	105	0.21
Electric fence standards	100	5	500	1
Labour hours ($30 per hour)	1	30	30	0.06
Total cost			**635**	**1.27 per metre**

2.4 Fencing configurations

For each stock exclusion policy option, decisions were made about the type of fencing required to exclude stock on different terrains across New Zealand. Rolling country was defined in the study as land with a slope greater than 7 degrees and less than 16 degrees, and steep country was defined as up to 28 degrees in slope. Fencing estimates do not allow for rocky, swampy or extremely heavy clay conditions.

Table 8 sets out the fencing configurations used to assign a physical fence type to each land use category, on different terrains, and with low, medium and high cost options. The unit price per metre for each configuration was determined by region and multiplied by the length of the streams that needed to be fenced to determine a total cost of fencing, discounted at 8 percent over 25 years for each stock exclusion policy option.

Only the costs of fencing streams, rivers and lakes were considered. The costs of fencing other waterbodies, such as wetlands and drains, were not included. The costs of providing stock crossings (such as bridges) were also not considered.

2.5 Stock water reticulation costs

The cost of fencing waterways may increase due to the requirement for other additional infrastructure costs to accompany the stock exclusion fencing, particularly in supplying an alternative source of stock drinking water. Such infrastructure may include culverts, water reticulation schemes and re-fencing

Table 8: Fencing configurations

Land use type	Terrain	Assumed fencing configurations		
		Low cost	Medium cost	High cost
Dairy platform	Flat	100% Cattle 1-wire electric	100% Cattle 2-wire electric	100% Cattle 2-wire electric
	Rolling	100% Cattle 2-wire electric	100% Cattle 2-wire electric	100% Cattle 2-wire electric
	Steep	100% Sheep/cattle non-electric wire	100% Sheep/cattle non-electric wire	100% Sheep/cattle non-electric wire
Dairy run-off	Flat	80% Cattle 2-wire electric, 20% temporary	90% Cattle 2-wire electric, 10% temporary	100% Cattle 2-wire electric
	Rolling	80% Cattle 2-wire electric, 20% temporary	90% Cattle 2-wire electric, 10% temporary	100% Cattle 2-wire electric
	Steep	80% Sheep/cattle non-electric wire, 20% temporary	90% Sheep/cattle non-electric wire, 10% temporary	100% Sheep/cattle non-electric wire
Dairy third-party grazing	Flat	60% Cattle 1-wire electric, 40% temporary	80% Cattle 2-wire electric, 20% temporary	100% Cattle 2-wire electric
	Rolling	60% Cattle 1-wire electric, 40% temporary	80% Cattle 2-wire electric, 20% temporary	100% Cattle 2-wire electric
	Steep	100% Sheep/cattle non-electric wire	100% Sheep/cattle non-electric wire	100% Sheep/cattle non-electric wire
Beef cattle	Flat	80% Cattle 2-wire electric, 20% temporary	80% Cattle 4-wire electric, 20% temporary	100% Sheep/cattle non-electric wire
	Rolling	80% Cattle 2-wire electric, 20% temporary	80% Cattle 4-wire electric, 20% temporary	100% Sheep/cattle non-electric wire
	Steep	100% Sheep/cattle non-electric wire	100% Sheep/cattle non-electric wire	100% Sheep/cattle non-electric wire
Deer	Flat	100% top-up fencing (80% of per metre cost = deer netting; 20% of cost = electric cattle 4 wire)	100% Deer netting	100% Deer netting
	Rolling	100% top-up fencing (80% of per metre cost = deer netting; 20% of cost = electric cattle 4 wire)	100% Deer netting	100% Deer netting
	Steep	100% Deer netting	100% Deer netting	100% Deer netting

paddocks. In some areas, extra infrastructure, such as water storage (tanks or dams), windmills, ram pumps and pipes, may need to be installed depending on the extent of existing stock water reticulation infrastructure already in place to service the rest of the farm.

Stock graze within a certain area from a water source, depending on topography, animal type, paddock size and climate. Strategic placement of water troughs can encourage more even grazing and improve productivity through improved pasture quality.

Reticulation costs represent a significant proportion of the total cost of fencing to exclude stock, being around 70 percent in some cases. There is uncertainty around estimates for reticulation costs because they are highly variable across different farm systems and in different parts of the country. An estimate for these additional costs was developed on the basis of providing an alternative water supply for one 50 hectare block of land; this is presented in Table 9.[6] The total estimated cost (materials only) for this infrastructure was $13 574.25.

Maintenance of the reticulation infrastructure is an additional annual cost and was estimated at 5 percent of the total capital cost per annum for reticulated water, depending on the type of water system.

To work out the total reticulation costs under each stock exclusion policy option, a 700-metre wide buffer was applied along the length of all streams that would be affected by each scenario (350 metres either side of the stream channel). The area of this buffer was then divided by 50-hectare blocks and multiplied by the cost of reticulation to supply one 50-hectare block.

Low and high cost estimates for reticulation were calculated by increasing the mid-range cost of $13 574.25 by 25 percent (high cost option = $16 967.81) and reducing the mid-range cost by 30 percent (low cost option = $9501.98). It was assumed this would allow for more or less of the above infrastructure, depending on the extent of existing reticulated systems on a property.

Riparian planting costs

The estimates do not account for the costs of riparian planting because it was too difficult to estimate these at a per unit level (that is, per metre) across New Zealand. This is because riparian management approaches are highly varied and are often tailored specifically for local conditions. Further work is required to estimate costs of riparian management across the country.

2.6 Total costs of fencing stock

The total costs of fencing (labour and material) plus stock water reticulation for each stock exclusion option are presented in Table 10. Low, medium and high cost options are shown. Both marginal fencing and reticulation costs (the additional costs

6 An estimate for a 10-hectare block is also presented in Lucock (2016, Table 9, p 21), however, it was decided that applying the costs of reticulating a 50-hectare block at a national scale was more conservative.

Table 9: Estimated costs to supply 50 hectares of land with reticulated stock drinking water

Component of additional reticulation (for a 50 hectare block)	Size and capacity	Number required	Estimated raw cost (NZ$)	Subtotal raw cost (NZ$)
Concrete trough	750 litres	5	442.50	2 212.50
Alkathene pipe	25mm diameter; 200 metres	5	312.56	1 562.80
Culvert	400mm diameter; 5 metres	1	603.30	603.30
Ram pump	20 500 litres/day	1	6 500.00	6 500.00
Water tank	25 000 litres	1	2 695.65	2 695.65
Total cost				**13 574.25**

Source: Lucock (2016, p 21)

incurred as more stock are progressively excluded) and cumulative costs (the additive costs of each stock exclusion option over and above current fencing requirements) are presented.

The costs of excluding all dairy cattle range from $25 million to $38 million discounted over 25 years. The costs are comparatively lower than for other land uses because 99 percent of dairy farms have already fenced off some of their Accord waterways (Brown, 2015).

Costs increase significantly when beef cattle are excluded on flat and rolling land. Additional costs range from $226 million to $533 million to fence 16 860 kilometres of Accord waterways, when compared with the costs of excluding only dairy cattle from waterways. It is estimated to cost an additional $7 million to $10 million to exclude deer on flat and rolling land from 260 kilometres of stream lengths.

Total costs over 25 years range from $258 million to $581 million over 25 years if all cattle (dairy and beef) and deer are excluded on flat and rolling land. Excluding all dairy and beef cattle and deer from Accord and non-Accord streams into steep hill country results in large increases in costs, with total costs over 25 years ranging from $1 billion to $2.2 billion.

Table 10: Total costs of fencing and reticulation for each stock exclusion policy option (discounted at 8 percent over 25 years)

#	Stock exclusion policy options	Marginal fencing costs (NZ$m)			Marginal reticulation costs (NZ$m)			Total cumulative costs (fencing and reticulation) (NZ$m)		
		Low cost	Medium cost	High cost	Low cost	Medium cost	High cost	Low cost	Medium cost	High cost
1	Baseline: Current fencing plus regional council requirements to be implemented by 2017							1 355.5	1 833.5	2 607.7
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	10.0	10.0	10.0	6.9	10.2	13.2	16.9	20.2	23.2
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	0.3	0.3	0.4	0.7	1.1	1.4	17.9	21.6	24.9
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	1.7	2.1	2.5	5.4	8.1	10.4	25.0	31.8	37.8
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	67.0	90.4	227.6	159.3	236.1	305.6	251.4	358.2	571.0
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	4.2	4.9	4.9	2.5	3.6	4.7	258.1	366.8	580.7
7	Exclude all cattle (dairy and beef) and deer into steep hill country (slopes up to 28 degrees) by 2017	274.2	343.6	676.4	489.7	725.4	939.2	1 021.9	1 435.8	2 196.2

2.7 Summary

Ninety-nine percent of dairy farms already have some fencing, along with 77 percent of sheep and beef farms and 89 percent of deer farms. Only 1379 kilometres of fencing would be required to exclude all dairy cattle.

The costs of excluding all dairy cattle range from $25 million to $38 million, with costs increasing significantly if beef cattle are also excluded. The total cost of excluding deer is not as expensive as excluding beef cattle because only 260 kilometres of fencing is required, compared with over 16 000 kilometres to exclude all beef cattle. The actual cost of deer netting is greater than the cost of non-electric and electric wire fencing.

A large component of the costs for beef cattle and deer is stock water reticulation. It is not known how many of New Zealand's waterways are currently used as a source of stock drinking water. In many cases, alternative (reticulated) water supplies may already be available, which would reduce the costs of the stock exclusion options. The costs of riparian planting have also not been quantified because of the variability that exists across the country, and the costs of stock crossings were not included.

3 *E. coli* in waterways from livestock incursions

To determine the benefits of stock exclusion, an understanding is needed of the degree of impact that stock exclusion practices can have on faecal pathogen loads in freshwater bodies. The value that people place on reductions in these loads can then be estimated in terms of a reduced likelihood of getting sick from contact with fresh water.

MPI commissioned the National Institute of Water and Atmospheric Research (NIWA), in partnership with AgResearch, to develop and run a national-scale *E. coli* Catchment Loads Model (ECLM) to predict the effects of different stock exclusion options on faecal pathogen loads and concentrations in fresh water (refer to Semadeni-Davies and Elliott, 2016). As outlined in Section 1, *E. coli* is used as an indicator of risk to human health from contact with fresh water in New Zealand.

The main source of faecal contamination in rural freshwater bodies is grazing livestock, although water fowl and other wild or feral animals can be additional sources. *E. coli* from stock enters the stream network via direct deposition of faecal matter into the stream or via indirect pathways including discharges of dairy effluent into streams, surface wash-off in areas of steep terrain, overland flow from excess irrigation and drainage via artificial drains (Collins et al, 2007; Muirhead, 2015). Cattle in particular are attracted to water both for drinking and thermoregulation. Restricting stock access to waterways, using stream fencing or riparian planting, is therefore a highly effective mitigation strategy (McKergow et al, 2007; Muirhead et al, 2011 and Quinn, 2012).

The impact of stock exclusion on other contaminants, most noticeably sediment, was also considered. However, a decision was made to focus only on the effect of stock exclusion on *E. coli* loads for the following reasons:

- The Catchment Land Use for Environmental Sustainability (CLUES) model is the best model for assessing the impact of contaminants at a stream level. Although the CLUES model analyses total sediment, it does not have the capacity to identify different sources of sediment within a catchment and the processes that influence sediment loads (for example, erosion or deposition). SedNetNZ is more effective for undertaking analysis at this level but is currently limited to only a selection of regions and is not available at a national level.
- Sediment has various "modes of impact", including direct physiological impacts. Modelling the effect of stock exclusion on the major modes of impact requires complex sediment modelling.
- The impact of stock exclusion on ecosystem health was not analysed because a method of modelling overall ecosystem health at a national scale has not yet been developed in New Zealand and was outside the capability of this study.

3.1 *E. coli* Catchment Loads Model

River network

The ECLM is a steady-state model that predicts in-stream *E. coli* base-flow loads for Accord and non-Accord waterways. The ECLM operates at the catchment scale (around 10 kilometres squared) and the smallest spatial unit is the River Environment Classification (Version 2) (REC2) river reach and its contributing area, referred to as a REC2 sub-catchment. A river reach in the REC2 is generally several hundred metres in length. Around 593 500 reaches are in the REC2 database. The combined length of all REC2 reaches in New Zealand is around 400 000 kilometres, of which nearly 168 600 kilometres are accessible to stock.

Reaches in the REC2 database were separated into Accord and non-Accord waterways, and further separated by slope class. It is assumed that all reaches within the REC2 database are permanently flowing and waterways with an order of 2 or more (that is, streams with upstream tributaries) meet the Water Accord. Head-water streams (that is, first order streams with no tributaries) are classed as Accord waterways as defined in Section 1.1, if the estimated width is greater than 1 metre. Stream depth is not assessed; instead, it is assumed that streams wider than 1 metre will have a depth of 30 centimetres. The lengths of Accord and non-Accord waterways by region are given in Appendix 1.

The model has been calibrated against measured mean annual *E. coli* loads from water quality monitoring stations included in the National River

Water Quality Network. The calibration statistics showed a high level of uncertainty in the model, which reflects the difficulty in modelling micro-organisms because of the high spatial and temporal variability of *E. coli* concentration measurements. Semadeni-Davis and Elliott (2016) provide a detailed discussion of the model uncertainty and errors in Section 5 of their report.

Land use

For each reach in the REC2, the ECLM estimates *E. coli* annual median and 95th percentile concentrations for baseflow conditions based on land use, slope and rainfall. Baseflow conditions were modelled on the understanding that most *E. coli* transport occurs following low intensity, high frequency rainfall events and that rivers are more accessible to people and stock during baseflow. Ten land use types are in the ECLM including farming of dairy, sheep and beef, deer and other stock.

The area of each land use was estimated using a three-step process:

» Differentiating between dairy, sheep and beef, and other farming activities spatially. The FarmsOnline database was used to extract aggregated information about the areas of different pastoral land use types across New Zealand (using information from the 2010 to 2015 period).[7]

» Because the stock exclusion options apply different levels of fencing for different types of dairy farms (dairy platform, dairy run-off on land owned or leased by the dairy farmer and third party grazing), the pastoral land use classes derived from FarmsOnline were further split on the basis of unpublished preliminary data from the 2015 Agricultural Production Survey undertaken by Statistics New Zealand. The survey gives information on the type and stocking rates for a range of farm enterprises. The dairy land use class was split for each super region into dairy platform and dairy run-off, relative to the proportion of cows and heifers in milk to dairy cattle not in milk. Non-milking dairy cattle were used to represent dairy cattle being grazed on land other than the milking platform. The proportion of non-milking dairy cattle on sheep and beef farms was used to separate out "dairy cattle grazing on land owned by a third party" from the intensive sheep and beef land use class.

» Spatial information from FarmsOnline was overlaid onto the Land Cover Database (Version 4; LCDB4) "pastoral" land use category mapping layer in the Geographic Information System to fill the few remaining gaps.

» The resultant land use map was then overlaid on the REC2 watershed layer to identify which land use types were present in each reach sub-catchment. NIWA calculated the total area for each land use type, within each reach sub-catchment and transferred this information into the ECLM.

The customised land use layer used to estimate *E. coli* loads from different pastoral land uses is based on a combination of FarmsOnline and LCDB4 spatial data. FarmsOnline was originally developed for biosecurity applications and, as such, has been adapted specifically for use in this project. The primary land use registered to landowners in FarmsOnline may not be the only land use on a given property, therefore, the modelled land use may differ slightly from the actual (real) land use. The level of detail available from FarmsOnline, however, was found to be higher than for other sources such as AgriBase.

E. coli loads

Each land use generates an *E. coli* load that is transported into waterways. This load is multiplied by the proportion of each land use within each catchment to determine the yield of *E. coli* from different land use types. The *E. coli* load was calculated for each REC2 sub-catchment.

Load: The load is the mass (or, for *E. coli*, the number of organisms). Two kinds of load are reported in this study. The reach load is the number of organisms produced by a reach sub-catchment that make it to the stream. This is the sum of the loads from each land use, which are in turn the product of the land use yield and area. The in-stream load is the sum of the loads from all of the upstream reaches plus the reach load less attenuation.

7 The information contained in FarmsOnline is recorded down to farm block scale, including the primary land use (the main type of agricultural activity on a property) and contact details of landowners. This information can be up to five years old, because MPI verifies data in five-yearly cycles. Therefore, the primary land use data used to build the ECLM covered the period between 2010 and 2015.

Yield: The mass (number of organisms) per unit area. In this study, yield refers to the number of organisms (peta or 1015) generated by each square kilometre of each land use type per year.

In each reach sub-catchment, additional *E. coli* loads from point sources (for example, meat works and sewage treatment plants) were added to give a reach total load. The reach total loads are routed through the stream network to determine in-stream *E. coli* loads and concentrations. The routing includes both in-stream attenuation and, for lake reaches, reservoir attenuation.

Other microbial sources may not have been accounted for in the ECLM. These could include background *E. coli* from natural sources, including wild pigs and birds, as well as unknown point sources, such as sewer or pumping station overflows in urban areas. For example, water fowl can contribute significant loads of *E. coli* to freshwater bodies (Wilcock, 2006 and Moriarty et al, 2011). Table 11 sets out the information used in the ECLM.

3.2 Effectiveness of fencing in reducing *E. coli* in fresh water

AgResearch provided an assessment of the farm-scale effectiveness of stream fencing mitigation for reducing *E. coli* levels in streams. A literature review was conducted to identify published data on the effectiveness of fencing stock to reduce *E. coli* concentrations in streams. Sixteen papers had suitable data; two papers addressed the fencing of deer and the remainder addressed fencing of beef or dairy cattle.

The effect of fencing on pastoral land is represented as a load reduction factor (LRF) or removal efficiency, which decreases the estimated *E. coli* yield proportionally for each stock type depending on the level of fencing. The percent effectiveness for *E. coli* removal from fencing ranged from 0 percent to 96 percent. The percentile values of 10 percent, 50 percent and 90 percent were therefore used to define the potential effectiveness for low, most likely and high effective categories respectively for each super region (as shown in Table 12). These three categories recognise the difficulty in providing an exact estimate of the effectiveness of any mitigation option.

Table 11: Information used in the *E. coli* Catchment Loads Model

Spatial data	Description
Waterway classification	River Environment Classification (Version 2) (REC2) sub-catchments. The REC2 database has 593 500 reaches, covering around 400 000 kilometres of waterways across New Zealand. Information covers length of waterway, sub-catchment area, relative size of the waterway, estimated mean annual flow rate, mean annual rainfall within the sub-catchment and average slope within the sub-catchment.
Land use information	FarmsOnline database, administered by MPI (spatial data showing the extent of different pastoral land uses, such as dairy and sheep and beef farming, across New Zealand).
Land use information	Underlying land use from the Land Cover Database, Version 4, relating to the year 2012. It was developed by Landcare Research.
Land use information	Estimated current extent of fencing in 2010 and 2015, modelled using the preliminary (October 2015) results of the Landcare Research *2015 Survey of Rural Decision Makers* (Brown, 2015).
Topography	Includes a digital elevation model with 20 metre contours.
Rainfall	Mean annual rainfall, sourced from the Catchment Land Use for Environmental Sustainability model geospatial database.
Water quality data	**Description**
E. coli concentrations	Annual median and 95th percentile concentrations of *E. coli*, previously calculated using the Random Forests Method Approach as part of the NEMaR3 program (Unwin and Larned, 2013). Based on a 2010 baseline.
E. coli concentrations	The NEMaR3 *E. coli* concentration model was calibrated against concentration data collected from 738 monitoring sites held in the National Water Quality Monitoring Network. The model was able to explain over 72.3 percent of the observed site-to-site variation.
E. coli concentrations	Locations of identified point sources of *E. coli* (such as discharges from dairy factories, meat works and wastewater treatment plants) and the known loads of *E.coli* discharged from each source.

Calculating the LRFs for excluding beef cattle on sheep and beef farms required a novel approach where the effect of beef cattle defecating in or near waterways had to be separated from that of sheep. Because sheep are not known to defecate directly into waterways in the same manner as cattle, no published data were available to quantify the effect of sheep and their access to waterways.

A modelling approach was used to determine the relative proportion of *E. coli* expected to be deposited directly in a stream from sheep and beef cattle. The relative proportion of *E. coli* load at the farm scale was then calculated from beef cattle. This proportion varied with the assumed sheep to beef cattle ratios (more sheep are in the south than in the north). The average sheep to cattle ratios were estimated from Beef + Lamb New Zealand financial survey data for the three super regions.

Only two papers discussed the effectiveness of fencing deer and provided separate point estimates of the effectiveness of stream fencing mitigation: 27 percent, 50 percent and 92 percent. Therefore, the percentile values to identify low, most likely and high effective mitigation categories could not be used. The numbers of deer are low relative to other stock types, and the data on existing fencing suggest almost all deer farms have already fenced Accord waterways. Few farms will run deer only, but a mixture of deer, sheep and beef cattle.

AgResearch recommended the same mitigation effectiveness used for dairy farms be used for deer in the analysis. This allows for increased effectiveness of fencing on deer farms relative to sheep and beef farms, which is consistent with current understanding of deer behaviour around waterways.

The effectiveness of fencing in preventing *E. coli* from pastoral land uses reaching freshwater waterbodies varies between different stock types and also by super region.[8] The three sets of LRFs cover the efficiencies that could be expected from fencing at the catchment scale and help convey the level of uncertainty inherent in this type of modelling. Note that the LRFs for sheep and beef land uses do not include the effect of excluding sheep.

Fencing of dairy cattle and deer is typically more effective in reducing *E. coli* loads from reaching waterways than fencing out cattle on sheep and beef properties. For example, across the northern North Island, fencing of dairy cattle and deer would reduce *E. coli* loads by 86 percent (at the highest level of effectiveness) while fencing to exclude beef cattle on sheep and beef properties would reduce *E. coli* loads by 73 percent (Table 12).

3.3 Modelled outcomes for reducing risks to human health

The ECLM produced annual median and 95th percentile *E. coli* concentrations for each stock exclusion option, nationally, regionally and at a super-region scale. The results are reported as the proportion of all waterways that would be assessed within each of the NOF bands based on either the

8 The number of respondents from the Survey of Rural Decision Makers (2015) and Agricultural Production Survey (2015) was small in selected regions of New Zealand, such as Westland. To protect the privacy of respondents, results were aggregated and have been analysed at a "super-region" scale. New Zealand was divided into three super regions: northern North Island (Northland, Auckland, Waikato, Bay of Plenty, Gisborne), southern North Island (Taranaki, Manawatū–Whanganui, Hawkes Bay, Wellington) and the South Island.

Table 12: *E. coli* load reduction factors for fencing to exclude stock, by super region and stock type

Description	Northern North Island			Southern North Island			South Island		
	Low	Most likely	High	Low	Most likely	High	Low	Most likely	High
Load reduction factors for fencing dairy cattle and deer	0.15	0.62	0.86	0.15	0.62	0.86	0.15	0.62	0.86
Load reduction factors for fencing beef cattle only on sheep and beef farms	0.13	0.53	0.73	0.11	0.44	0.61	0.10	0.40	0.55

Source: Muirhead (2016).

modelled 95th percentile *E. coli* concentrations (which tell us if a waterway is swimmable or suitable for primary contact recreation activities) or the annual median *E. coli* concentrations (which provide an assessment of whether a waterway is suitable for secondary contact recreation activities).

For ease of interpretation, the results are reported at a national scale for each stock exclusion option. They are based on the "most likely" LRF applied in the ECLM. Results obtained using the "low" and "high" load reduction factors are presented in Appendix 6. More detailed results, including results by region, can be found in Semadeni-Davis and Elliott (2016).

Outcomes for secondary contact recreation in fresh water

Table 13 shows the impact of stock exclusion options on the proportion of Accord and non-Accord waterways that are fenced and movements between the NOF bands. The numbers in brackets are the changes in stream length fenced. Note that options 2 to 6 only apply to Accord waterways so the changes in stream lengths fenced for these options are changes to Accord streams only. Option 7 applies to both Accord and non-Accord streams.

Stock exclusion policies would only have a minimal effect on the risk of getting sick from wading and other secondary contact recreation, because Accord and non-Accord waterways already meet the national bottom line for secondary contact recreation. A very low number of waterways across New Zealand currently present a high risk of infection to users engaging in secondary contact recreation; less than 0.01 percent nationally.

Little difference exists between current fencing and regional council requirements (the baseline) and options 2 to 4, because up to 94 percent of dairy cattle nationally have already been excluded from Accord streams. The increased length of fencing nationally under these options is only 726 kilometres, 77 kilometres and 576 kilometres respectively. Because there is little capacity for extra fencing along Accord streams under these policy options, the increase in waterways in Band A of the NOF is minimal (1053 kilometres of stream length).

Excluding beef cattle results in an extra 16 860 kilometres of streams requiring fencing nationally. Regionally, this amounts to a 4 percent increase in Accord stream lengths in Band A for the northern North Island and an increase of 1 percent each for the southern North Island and South Island. The length of Accord streams with an estimated annual median concentration in Band D remains the same as the current situation in Southland (1.5 kilometres), but it decreases to 11 kilometres for Waikato because further fencing could be erected in the reaches outside the Priority One zones. The region most affected by option 4 is Northland, which

has a 12 percent increase in Accord stream lengths with estimated annual median concentrations in the A Band. Overall, an additional 4922 kilometres of stream length would meet the A Band requirements if beef cattle are also excluded.

Excluding deer results in an additional 260 kilometres of streams requiring fencing. Given this, the results for options 4 and 5 are similar (with an additional 127 kilometres of stream length in Band A). Overall, there is an increase of around 6100 kilometres of streams with estimated annual median concentrations of *E. coli* within Band A, compared with the current situation when all dairy and beef cattle and deer are excluded from freshwater bodies.

Option 7 (that is, fencing off all dairy and beef cattle and deer from all streams into steeper hill country) sees an additional increase of 30 658 kilometres of stream lengths with an estimated annual median concentration of *E. coli* in Band A, compared with the current situation. This is an increase of 8 percent nationally, bringing the total proportion of streams within Band A for secondary contact recreation to 97 percent.

Outcomes for primary contact recreation in fresh water

Table 14 shows the proportion of Accord waterways in each of the *E. coli* NOF bands for primary contact recreation (based on 95th percentile measurements) for each stock exclusion option. Only Accord waterways are shown because non-Accord waterways are too small for full immersion activities. Option 7 applies to both Accord and non-Accord waterways,

Table 13: Proportion of waterways (Accord and non-Accord) nationally within each National Objectives Framework *E. coli* band for secondary contact recreation (based on annual median *E. coli* concentrations) for each stock exclusion option

Option	Description	Suitable for secondary contact recreation			Not suitable
		Low risk of infection		Moderate risk of infection	High risk of infection
		A	B	C	D
1	Baseline Current level of fencing to exclude stock, plus regional council requirements to be implemented by July 2017	89.37% (357 551)	10.40% (41 613)	0.23% (911)	0.0% (14)
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	89.49% (358 050)	10.28% (41 143)	0.22% (884)	0.0% (14)
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	89.50% (358 083)	10.28% (41 113)	0.22% (879)	0.0% (14)
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	89.63% (358 604)	10.15% (40 593)	0.22% (879)	0.0% (14)
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	90.91% (363 526)	8.88% (35 493)	0.21% (835)	0.0% (13)
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	90.94% (363 653)	8.85% (35 369)	0.21% (832)	0.0% (13)
7	Exclude dairy, beef and deer into steep country (slopes up to 28 degrees) (Accord and non-Accord waterways)	97.03% (388 209)	2.86% (11 460)	0.10% (417)	0.0% (4)

Note: Accord waterways are deeper than 30 centimetres and wider than 1 metre. Non-Accord waterways are smaller than this.
A, B, C and D refer to the National Objectives Framework (NOF) bands. The numbers in brackets are the length of stream kilometres in each NOF band.

but only the results for Accord waterways are shown here.

Table 14 shows that 43 percent of Accord waterways are currently not swimmable (do not meet the minimal acceptable state in the NOF) based on current fencing practices and existing regional council requirements, while 48 percent are in the A Band.

As with secondary contact recreation, minimal improvements will be achieved from excluding all dairy cattle because 94 percent of streams on dairy farms are already fenced (an additional 251 kilometres of stream length will be in the A or B bands for primary contact recreation). Improvements will be made if beef cattle are fenced off streams with an additional 1685 kilometres of stream length within the A or B bands. An additional 61 kilometres of stream length will meet the A and B Band requirements for primary contact recreation if deer are also excluded from Accord waterways on flat and rolling land.

Overall, there is an associated increase of around 2000 kilometres nationally in stream lengths that meet the acceptable state for primary contact recreation, compared with the current situation if all dairy and beef cattle and deer are excluded from Accord waterways on flat and rolling land.

Excluding dairy and beef cattle and deer into the hill country will increase the percentage of Accord waterways that are swimmable (Band A and B) from 57 percent to 60 percent, compared with the current situation (an additional 9297 kilometres of Accord waterways in the A or B bands).

3.4 Summary

Fencing to exclude stock from waterways will have a moderate effect on the number of *E. coli* organisms present in freshwater bodies in New Zealand. The effects are moderate because most dairy farms are already fenced. Significant improvements to the proportion of waterways that are swimmable will only be achievable if dairy and beef cattle and deer are excluded from water.

Table 14: Proportion of Accord waterways nationally within each National Objectives Framework *E. coli* band for primary contact recreation (based on 95th percentile *E. coli* concentrations) for each stock exclusion option

Option	Description	Swimmable bands		Below minimal acceptable standard
		A	B	
1	Baseline Current level of fencing to exclude stock, plus regional council requirements to be implemented by July 2017	47.96% (147 182)	9.41% (28 887)	42.62% (130 805)
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	47.99% (147 269)	9.43% (28 951)	42.58% (130 653)
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	47.99% (147 275)	9.44% (28 968)	42.57% (130 631)
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	48.0% (147 312)	9.45% (29 008)	42.54% (130 553)
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	48.32% (148 282)	9.69% (29 723)	41.99% (128 868)
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	48.33% (148 324)	9.69% (29 742)	41.97% (128 807)
7	Exclude dairy, beef and deer into steep country (slopes up to 28 degrees) for Accord waterways only	49.99% (153 417)	10.41% (31 948)	39.60% (121 508)

Note: Accord waterways are deeper than 30 centimetres and wider than 1 metre. Non-Accord waterways are smaller than this.
A and B bands refer to the National Objectives Framework (NOF) bands. For a waterway to be safe to swim in, the *E. coli* load should be within the A or B band. The numbers in brackets are the length of stream kilometres in each NOF band.

4 Valuing improvements in freshwater quality

The section outlines the development and results of a choice experiment used to identify and measure New Zealand residents' preferences for several water quality outcomes. These improvements can enhance recreational opportunities, cultural values and habitat biodiversity, providing benefits to New Zealanders.

Once the value that people place on different water quality improvements is known, such as a reduction in the likelihood of getting sick from contact with water, the value that is attainable from excluding stock from waterways can be determined in economic terms.

The selection of suitable economic measurement tools to value policy benefits is driven primarily by the availability of appropriate data that can describe the value of policy outcomes to individuals. In the case of the water quality outcomes considered here, these are not traded in markets and, therefore, no suitable market prices are available that could be used to measure changes in benefits. Economists instead draw on non-market valuation methodologies, of which the choice experiment approach is appropriate for this context.

Choice experiments have, for over four decades, been applied in economics to value a variety of goods and services, such as transport, cultural heritage, environmental quality and health care. This approach has been widely applied to value freshwater resources internationally and has an established New Zealand literature.

The choice experiment method simulates market observations by creating a hypothetical market scenario within a survey that enables people to indicate their preferences for changes in water quality and the costs associated with them. In this way, a choice experiment produces information on quantities and prices similar to that found in real markets, which can then be analysed to measure the benefit of changes in water quality.

MPI commissioned the Agribusiness and Economics Research Unit at Lincoln University to help in determining the main values of importance to New Zealanders in terms of water quality, and to provide an estimate of peoples' willingness to pay (WTP) to see marginal improvements in these areas of water quality (see Tait et al, 2016).

4.1 Identifying non-market values

Three areas of impact or probable quality benefits have been identified as the main outcomes of stock exclusion that are relevant in the context of a national-level survey. These are:

1. **HUMAN HEALTH RISK:** Farm animals produce significant quantities of waste that contains bacteria that cause disease and make people sick. Keeping farm animals out of waterways helps limit the amount of waste that reaches the waterway. This results in a reduced risk of people becoming sick. Health risk is measured by the number of people who have contact with a waterway and then become sick, adopting the health risk categories (bands) used in the NOF. The data from NIWA's assessment of changes in *E. coli* loads from stock exclusion (outlined in Section 3) were used to inform the health risk from *E. coli*.
2. **ECOLOGICAL QUALITY:** Preventing farm animals from entering waterways can enhance the range of species living within the freshwater environment (biodiversity) and provide food and habitats for flora and fauna. This is achieved by enabling the establishment of overhanging vegetation creating shade and helps keep water temperatures more stable. This also provides shelter and safety from predation for aquatic life. The vegetation improves the range of habitats available for aquatic life to occupy and thrive in.

   Ecological quality was measured using Macroinvertebrate Community Index (MCI) scores, which are based on the presence (or absence) of different kinds of invertebrates, such as insects, worms and snails, that respond to changes in habitat condition. Higher index scores indicate healthier waterbodies. Median MCI scores were assessed for 876 monitored sites throughout New Zealand between 2012 and 2013.
3. **WATER CLARITY:** Fences prevent farm animals from accessing waterways and causing damage to banks and beds of waterbodies. Erosion of banks and river beds introduces extra sediment into the waterway. Sediment in waterways reduces

water clarity and visibility, and settles on beds. This can smother aquatic life and prevent vital biological processes from functioning normally, and destroy spawning areas. Raised river or stream beds can increase the risk of flooding. High levels of sediment also make swimming and other recreation activities unpleasant and unsafe.

Water clarity is influenced by the amount of sediment suspended within the water column. A common measurement used to estimate water clarity in New Zealand is the Black Disk method. This is used to determine the depth through water that is visible to the human eye. Typically, greater visibility indicates lower sediment levels. Median Black Disk measurements taken at 675 monitored sites throughout New Zealand were analysed for the years 2012 to 2013.

4.2 Attributes and levels

The levels for each water quality attribute are presented in Table 15. The levels are represented as the percentage of freshwater sites across New Zealand that achieve a given level of quality. For each attribute, these levels must sum to 100 percent, and they are presented as pie charts in Figure 3. These charts show the relative proportion of waterbodies in a particular quality category. This design allows estimates to be generated of the value of increasing the proportion of waterways within a particular quality category.

The type of waterway improved can influence individual management preferences, so a priority waterbody type management attribute was included to capture differing preferences for streams, rivers and lakes. Streams were defined as small low-flow waterways less than 5 metres wide; rivers were defined as permanently flowing waterways wider than 5 metres; and lakes were defined as large permanent bodies of water greater than 2 hectares in area.

These definitions are more specific than those used for the rest of the study (that is, for estimating the costs and impact on *E. coli* concentrations in fresh water, where non-Accord and Accord waterways were the focus of the analysis) because it was necessary to describe waterways in a manner that respondents could identify with. The results of the non-market valuation are still comparable with the other definitions.

The location of water quality improvements may influence individual management preferences, so a priority management location attribute was included to capture differing preferences for improvements

Table 15: Attribute descriptions and levels for choice tasks

Attribute	Management outcome	Levels (% of waterbodies achieving outcome across NZ)			
Human health risk	1/10 visitors sick each year	0	10	20	30*
	1/20 visitors sick each year	0	10*	20	
	1/100 visitors sick each year	10*	20	30	40
	1/1000 visitors sick each year	50*	60	70	80
Ecological quality	Poor: MCI score less than 80	10	20	30	40*
	Moderate: MCI score between 80 and 99	10	20*	30	
	Good: MCI score greater than 100	40*	50	60	70
Water clarity	Poor: Visibility of 1.1 metres or less	20	40	60*	
	Moderate: Visibility between 1.2 and 2.4 metres	20*	30	40	
	Good: Visibility of 2.5 metres or more	20*	30	50	
Management priority location		No priority*	Local	Regional	
Management priority waterbody type		No priority*	Streams	Rivers	Lakes
Annual cost ($NZ)		0*, 50, 100, 150, 200			

Note: * Denotes levels of "no waterway animal management" alternative used in each choice set.
MCI = Macroinvertebrate Community Index.

that occur locally (within 50 kilometres of a respondent's domicile) and those that occur within a respondent's region.

To determine the proportionate split of waterbodies across the current quality categories, data were obtained from Land, Air, Water Aotearoa, a collaboration between New Zealand's 16 regional and unitary councils, the Cawthron Institute, Ministry for the Environment and Massey University.

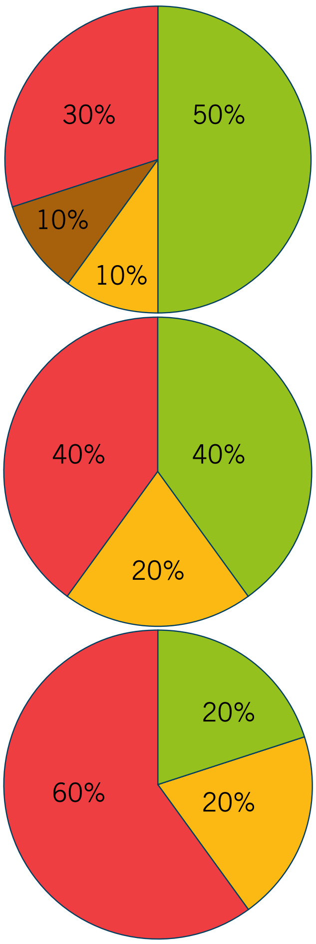
4.3 Design of the survey

A sample of 2032 New Zealand residents was surveyed online in September 2015. The sample was obtained from Research Now. This sampling method allowed for the pre-stratification of the sample by age, gender, income and regional location. Statistical analysis of the demographic information collected from respondents confirmed the survey sample overall was representative of the New Zealand population.[9] This level of stratification would not have been possible if drawing a sample from the commonly used Electoral Roll, which does not include most of these variables. This method has previously been used to value freshwater resources in New Zealand, though at a regional scale.

The only area in which the sample was skewed was level of education, with respondents tending to be more highly educated; for example, 30 percent of respondents listed an undergraduate diploma, certificate or degree as their highest qualification, while 14 percent of the population is in this

9 Statistical analysis showed that the distribution of the sample demographic was not statistically different from the national population distribution; the P-values for each of the demographic variables were greater than 0.1 (ranged between 0.34 for household size, to 0.90 for age) with the exception of education.

Figure 3: Example of pie chart format of water quality attributes: human health, ecological quality and water clarity



Proportion of all waterbodies across NZ with visitors' chance of getting sick

- Less than 1% chance of getting sick (1/1000 people/year)
- About a 1% chance of getting sick (1/100 people/year)
- About a 5% chance of getting sick (1/20 people/year)
- About a 10% chance of getting sick (1/10 people/year)

Proportion of all waterbodies across NZ with level of ecological quality

- GOOD: MCI score less than 80
- MODERATE: MCI score between 80 and 90
- POOR: MCI score greater than 100

Proportion of all waterbodies across NZ with level of water clarity

- GOOD: Visibility of 2.5m or more
- MODERATE: Visibility between 1.2 and 2.4m
- POOR: Visibility 1.1m or less

Note: MCI = Macroinvertebrate Community Index.

category nationally. Table 16 sets out the sample characteristics of the survey. Important points to note include:

» even distribution across 16 regions; for example, 33 percent of New Zealand's population live in Auckland, and 22 percent of the survey respondents were from Auckland;
» 50 percent of respondents were female (51 percent of the national population is female);
» the age of survey respondents typically reflected that of the wider national population; for example, 16 percent of survey respondents were aged between 55 and 64 years (this proportion is 15 percent nationally).

Before the full launch of the survey, a pilot study was conducted with a sub-sample of the population (300 people) to evaluate interconnections among questions, the questionnaire and the implementation procedure. The survey was also tested via a series of six cognitive interviews, to assess whether respondents comprehended questions as intended by the researcher and the questions could be answered accurately. For this study, cognitive interviews were conducted to identify wording, question order, visual design and navigation problems. Six interviews were conducted across a mix of gender, age and occupation, each with a duration of 1.5 to 2.5 hours. Some of the interviewees had specialised knowledge of a particular aspect of questionnaire quality, such as choice experiment design elements and end-user usability of the online survey format being used.

Choice tasks

In choice experiments, respondents are presented with a series of choice tasks. For each choice task, respondents choose between at least two broad options. In this study, the options represent alternative scenarios for a stock exclusion policy. Each option is described by several attributes describing water quality outcomes resultant from stock exclusion, for example, improved human health risks or ecological quality. These are called "choice sets".

In each choice task, the combinations of attributes are systematically varied to denote different management options. Respondents are asked to choose the option with the combination of outcomes they prefer. It was assumed the options chosen by respondents are what they think are best for them personally. Each choice set comprises three options:

» **OPTION 1:** "No waterway animal management" that represents an option in which a stock exclusion policy is not expanded from current levels and, therefore, no additional cost is imposed on respondents. This option is the same for all choice sets and is known as the constant base that respondents compare other options against.
» **OPTIONS 2 AND 3:** Represent options in which a stock exclusion policy is expanded, and contain improvements in water quality outcomes for each attribute compared with the constant base option. These two management change options do impose an additional annual cost on respondents.

Table 16: Survey sample characteristics

Demographic variable		Sample distribution (%)	NZ population distribution (%)[1]
Age [p = 0.90][2]	65 years or more	21	19
	55–64 years	16	15
	45–54 years	19	19
	35–44 years	17	18
	25–34 years	17	16
	18–24 years	10	13
Gender [p = 0.84]	Female	50	51
Education [p = 0.00]	High school	28	50
	Trade or technical qualification or similar	22	9
	Undergraduate diploma, certificate or degree	30	14
	Postgraduate degree	18	6
	None	2	21
Occupation[3] [p = 0.74]	Unemployed	5	4
	Retired	19	14
	Unpaid voluntary work	1	1
	Student	7	6
	Paid employment	60	65
	Home duties	7	8
Personal income [p = 0.38]	Loss	1	1
	$0 – $20 000	25	38
	$20 001 – $40 000	30	26
	$40 001 – $50 000	12	10
	$50 001 – $70 000	16	13
	$70 001 – $100 000	9	8
	$100 001 or more	7	6
Household size [p = 0.34]	One	15	22
	Two	40	34
	Three	17	17
	Four or more	28	27
Region [p = 0.81]	Auckland	22	33
	Bay of Plenty	7	6
	Canterbury	12	13
	Gisborne	1	1
	Hawke's Bay	6	4
	Manawatū–Whanganui	7	5
	Marlborough	2	1
	Nelson	2	1
	Northland	4	4
	Otago	4	5
	Southland	2	2
	Taranaki	4	3
	Tasman	1	1
	Waikato	12	10
	Wellington	13	11
	West Coast	1	1

Notes:

1 Distributions from Statistics New Zealand Census 2013.

2 Values in brackets are p-values for Pearson's Chi-squared test of the null hypothesis that the frequency distribution of the observed sample demographic variable is consistent with the population distribution provided by Statistics New Zealand Census 2013 data. A p-value less than 0.1 indicates a statistically significant difference between the distributions; p-values greater than 0.1 indicate that the demographic distribution is not statistically different from the population and therefore is representative of the general population.

3 Population distributions from 2013 Household Labour Force Survey.

Respondents are shown six different choice sets, and for each they are asked to select the option that achieves their preferred combination of outcomes. Figure 4 provides an example of a choice set presented to respondents.

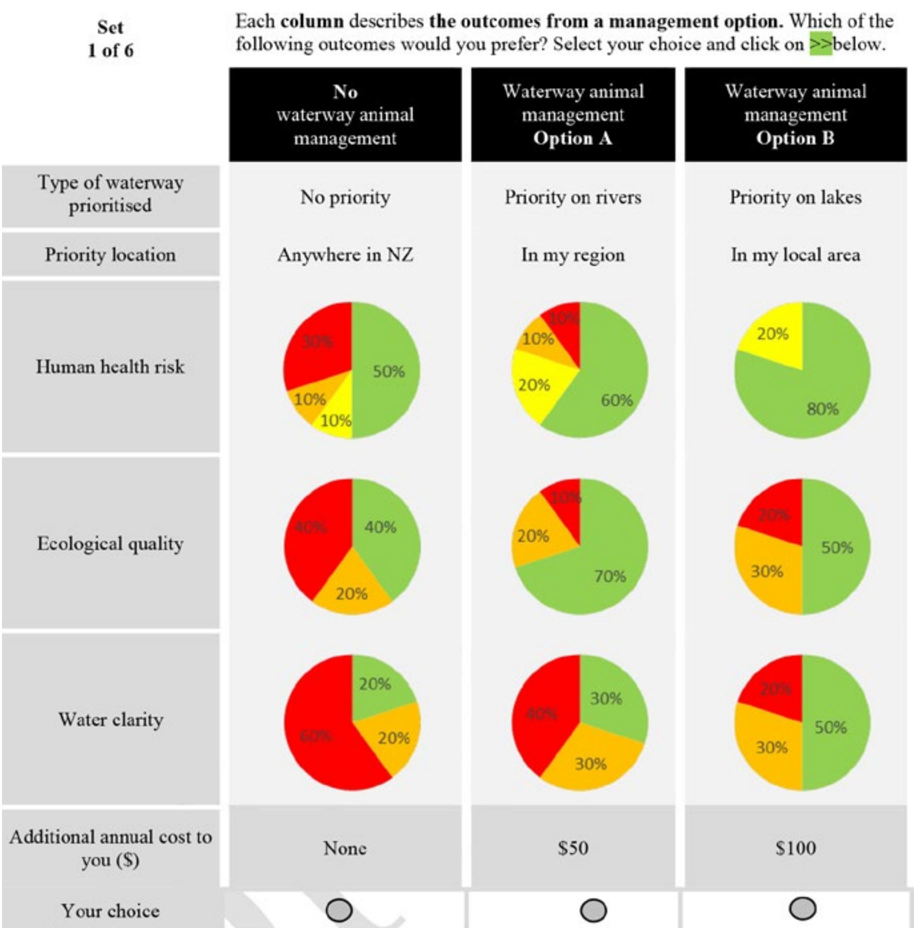
The dataset collected in the choice experiment survey comprises water quality outcomes for each of the selected and non-selected policy options in each choice set (10 825 choices in total). The data were analysed using statistical methods to explain the variation between the selected and non-selected policy options. The relative importance placed on each policy outcome by respondents, and which outcomes were preferred on average, could then be identified.

A lot of variation exists in the way people make choices between options, which may be driven by differences in individual preferences or by unobserved components of choice. A statistical model (a Generalised Mixed Logit model (GMXL)) was applied in this study to accommodate both forms of respondent variation. The GMXL extends the commonly used Random Parameter Logit model (also known as a Mixed Logit model) to capture differences in respondents' preferences, as well as identifying the different sources of variance in the unobserved component of respondent choice.

These models were applied to estimate the monetary value of different preferences expressed by respondents to the survey. This value is commonly referred to as marginal willingness to pay. WTP estimation provides a means of "trading off" between different outcomes (levels of improvement) for each attribute (human health risk, ecological quality and water clarity), and the cost involved in achieving those outcomes.

The models estimate a parameter for each outcome that indicates the relative contribution to the respondent's welfare from each policy outcome, including the financial cost required to enable policy implementation. Examining ratios of these parameters shows how much of a particular outcome people

Figure 4: Example of a choice set presented to respondents



would be willing to trade off to enjoy more of another preferred outcome. When respondents trade off an amount of money for a water quality outcome, this calculation measures respondents' WTP for a per unit change in that outcome. WTP can account for factors that might be influencing preferences, such as the demographics of the sample population surveyed.

Changes in welfare measure how much better (or worse) off someone is after a policy is implemented, and this depends on what outcomes people prefer. Changes in welfare are measured by the willingness to pay for a quality improvement. This is the change in disposable income that holds utility or satisfaction constant given a change in water quality. The difference in utilities between a no policy outcome and a policy outcome are the measures of welfare.

The choice experiment method assumes individuals know how much they would be willing to pay for higher levels of a non-market good and that this is constrained by their income and preferences to consume market goods. In other words, respondents are able to assess trade offs between things they might typically purchase in markets with goods they have never purchased in a market situation. The respondents' familiarity with freshwater resources and the associated water quality being valued can therefore influence choice experiment performance.

Well-informed respondents with relevant knowledge or experience will be able to provide consistent indications of their WTP, while those who are unfamiliar and have a low understanding of the good being valued may provide less reliable estimates. For those respondents, it is possible that focusing on a particular environmental good may raise its importance, compared with a situation where it is considered as one good among many. A well-designed choice experiment clearly explains the policy context and environmental outcomes, expresses outcomes in terms relevant to participants and identifies unreliable answers.

Other limitations of choice experiments include those common to all surveying methods; respondents are assumed to answer honestly and rationally and consider the survey to be consequential. People are also assumed best able to know their own preferences; an assumption common to all economic methods.

4.4 Freshwater perceptions and experiences

This section summarises survey respondents' perceptions of freshwater quality in New Zealand. A more detailed account is found in Tait et al (2016).

Survey respondents were asked to describe what they thought of the overall quality of river, lake and stream environments in New Zealand, based on the scale shown in Figure 5. As shown in Figure 6, the greatest levels of satisfaction were for lakes, with 52 percent of respondents believing lake environments to be in a satisfactory or very satisfactory condition. Lakes also had the lowest levels of dissatisfaction, with 25 percent of respondents believing lake environments to be in an unsatisfactory or very unsatisfactory condition.

Stream environments were perceived to be in the worst condition, with 39 percent of respondents believing stream environments to be in an unsatisfactory or very unsatisfactory condition and 38 percent believing stream environments to be in a satisfactory or very satisfactory condition.

The study found that respondents' preferences for human health risk, ecological quality and water clarity were likely to be influenced by the amount of contact they have with waterways. This contact is quantified in Figure 7. Relatively few respondents had not visited a river, lake or stream at least once in the previous 12 months (11 percent). Respondents were most likely to have visited rivers in the previous 12 months (78 percent), followed by lakes (64 percent) and were least likely to have visited streams (56 percent). Notably, respondents were more likely to visit all three waterbody types (37 percent) than just a single waterbody type alone (19 percent).

A notable proportion of the survey respondents indicated that they used freshwater resources very frequently. Respondents who indicated they had visited a river, lake or stream were then asked which activities they engaged in at these waterbody types.

The main results for this question were as follows:

Rivers:	The highest number of visitors to rivers went there for sightseeing (73 percent), followed closely by walking, running or jogging (71 percent) and then picnicking (68 percent).
Lakes:	The same pattern of behaviour is revealed as for river visitors but at a lower frequency. The highest number of visitors to lakes went there for sightseeing (53 percent), followed closely by walking, running or jogging (47 percent) and then picnicking (46 percent).
Streams:	Similarly, visitors to streams most often went there for walking, running or jogging (38 percent), followed by sightseeing (32 percent), though nature and birdwatching are now the third most engaged in activities by stream visitors (31 percent).

Figure 5: Scale of overall environmental condition for rivers, lakes and streams

Figure 6: Respondent perceptions of overall quality of river, lake and stream environments in New Zealand

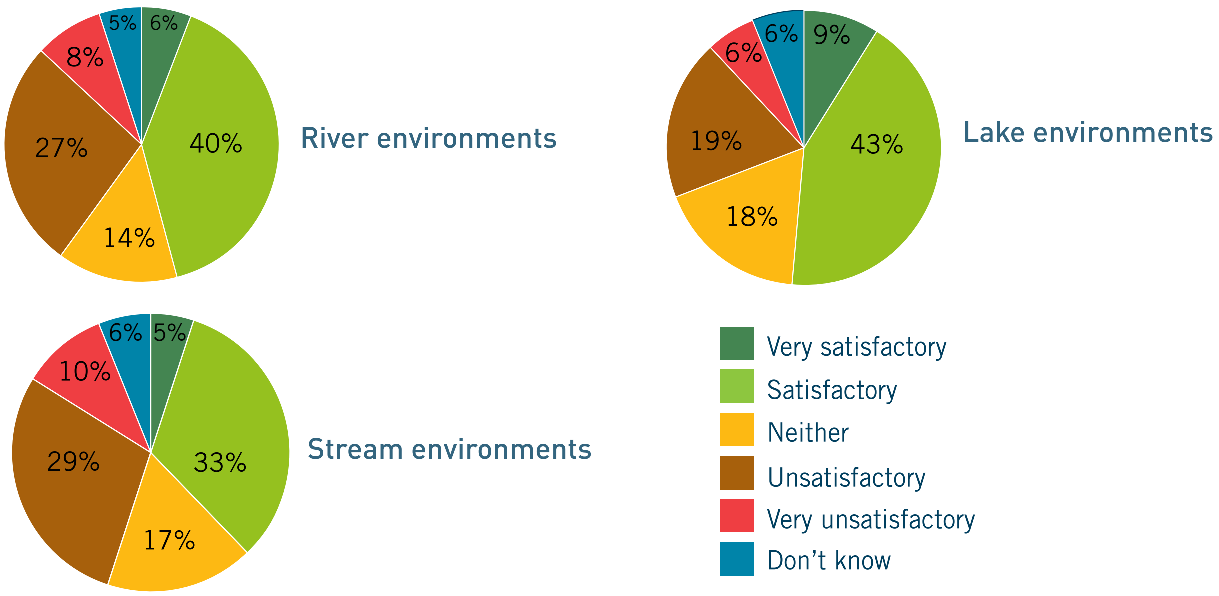
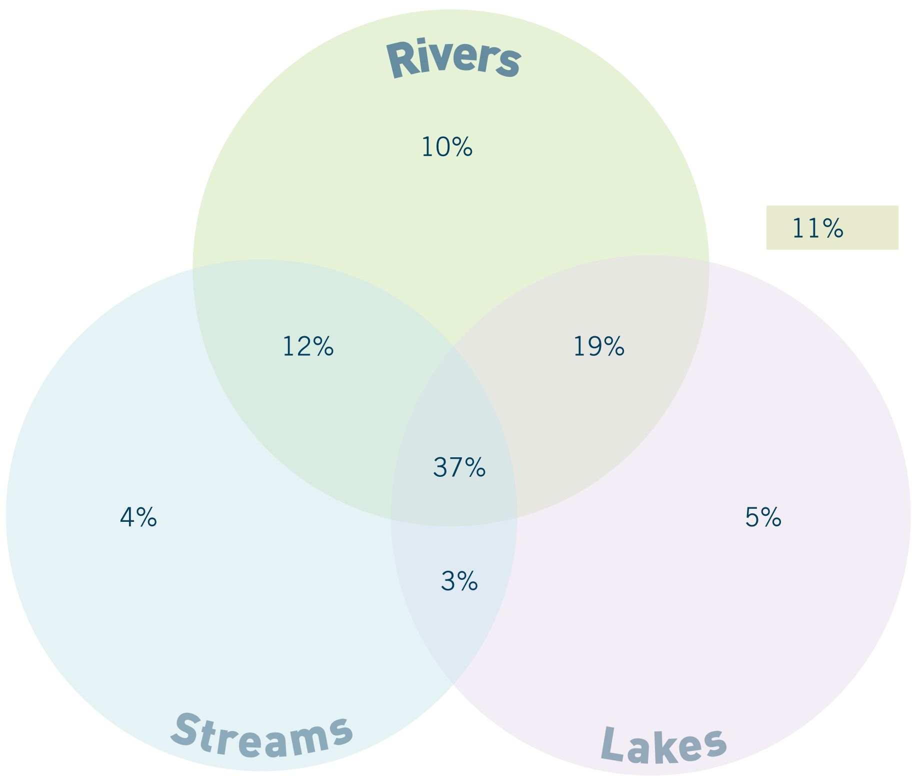


Figure 7: Proportion of survey respondents visiting rivers, lakes and streams within the previous 12-month period (2014–15)



More visitors engaged in visual and secondary recreation activities, rather than primary recreation such as swimming and fishing. This is illustrated in Figure 8, which shows that, in total (across rivers, lakes and streams), 83 percent of visitors engaged in secondary recreation activities, while only 53 percent engaged in primary recreation. Few respondents (9 percent) participated in one type of activity alone.

Respondents who engaged in activities were also asked to indicate the distance they travelled on their most recent visit for each particular activity. The highest average number of visits overall was to rivers (9 visits), followed closely by streams (8 visits) and lakes (around 4 visits). The average distance travelled to lakes was the longest (34 kilometres), while respondents travelled considerably shorter distances to visit rivers (9.6 kilometres) and streams (2.2 kilometres). The furthest distances travelled to each waterbody type were all for sightseeing activities. The closest distances travelled by visitors were to streams for rowing, boating or canoeing.

4.5 Choice experiment results

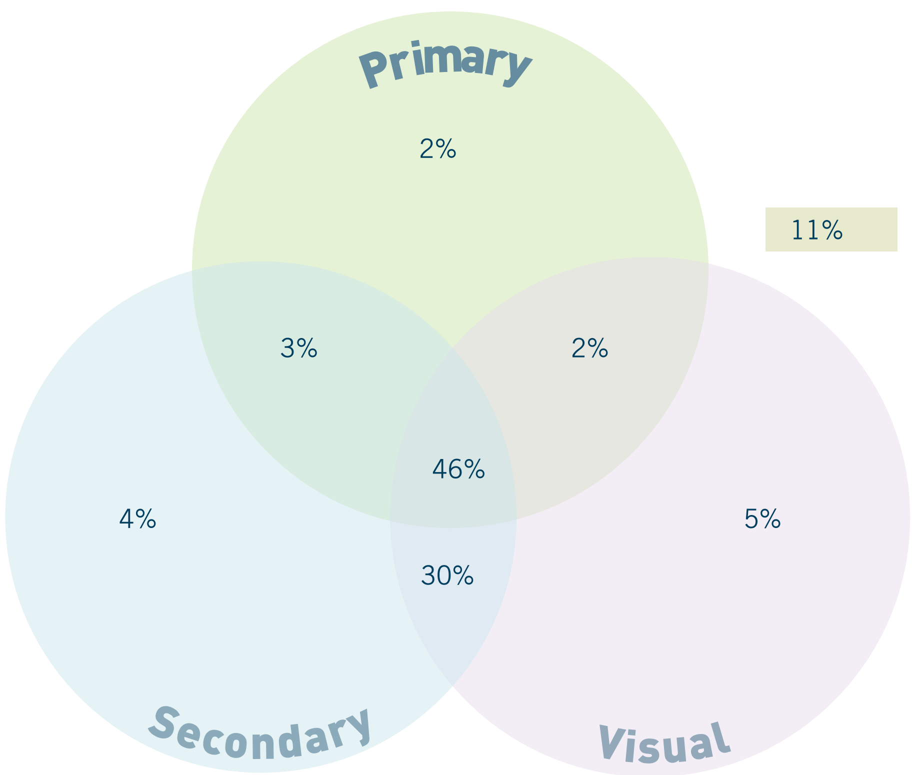
The results of the choice experiment provided insight into respondents' preferences for different ways of managing freshwater resources to improve water quality attributes (that is, reduced human health risk, improved ecological quality and water clarity).

The econometric (Generalised Mixed Logit) model used to analyse the results of the choice experiment performed well,[10] and all the water quality attributes were highly statistically significant (meaning they were confirmed to be important factors in the respondent's choice of freshwater management options). More information on the econometric modelling can be found in Tait et al (2016).

The results showed respondents are more likely to choose management options that have higher levels of water quality outcomes and are less

10 Model performance was confirmed with a McFadden Pseudo R^2 equal to 0.24. Further technical detail regarding model performance can be found in the technical report by Tait et al (2016, Table 3, Section 3.3).

Figure 8: Proportions of survey respondents participating in primary contact, secondary contact and visual (non-contact) recreation activities



likely to choose options imposing greater financial contributions. Changes in the proportion of waterways with good water clarity had the largest influence on respondents' choices.

Other important findings included:

- » the total number of times respondents visited all types of waterways was a significant influence on their preferences for water quality outcomes;
- » respondents preferred improvements in the highest quality categories for each water quality outcome over increases in lower quality categories;
- » respondents preferred to have streams prioritised first (for management), followed by lakes and then rivers;
- » improvements local to respondents were preferred over regional improvements, and regional improvements within the respondent's region were preferred over those outside their region;
- » respondents were more likely to choose a stock exclusion policy option if they perceived current overall water quality to be poor, or they thought that freshwater resources were important to provide habitats for plants and wildlife;
- » frequent visitors to streams, rivers or lakes were willing to pay more (that is, had a higher WTP) than those who were less frequent visitors;
- » those with higher incomes were willing to pay more than others for improvements in water quality attributes;
- » older people had a higher WTP for improvements in water quality attributes than younger people;
- » respondents preferred to have stock exclusion as a management option for freshwater resources than to not have it at all.

Three important aspects were included in the choice experiment survey to help confirm the validity of responses and quantify sources of bias and uncertainty:

1. Respondents were asked to indicate which, if any, of the water management outcomes being considered they had ignored when answering the survey.
2. A series of questions was asked following the choice sets to identify "protest behaviour" by respondents.
3. A series of questions was asked after each choice task to identify any sources of variance in the way respondents were making their choices.

Generally, the different water management outcomes included in the survey were ignored to a similar degree by different respondents, at a relatively low level. Twenty-one percent of the sample consistently chose the "no cost option" in all of the choice tasks, and it was found that 53 percent of these were protest responses. Such responses were excluded from the analysis to enable a more realistic assessment of peoples' willingness to pay. Removal of these responses did not have a statistically significant effect on WTP estimates.

Willingness to pay for improvements in water quality

The choice experiment results were run through the econometric (GMXL) model to estimate respondents' WTP for different water management outcomes. WTP is an estimate of how much money a respondent would be willing to give up for a change in the relevant water quality outcome, and is calculated using the ratio of an attribute parameter and the cost parameter.

The estimates of WTP in Table 17 show respondents would be willing to pay $3.31 for each percentage point increase in the amount of waterways that are a low risk to human health (where there is a risk of 1 in 1000 people becoming infected by pathogens). For example, if only 22 percent of rivers are low risk at present, respondents would be willing to pay $6.62 to have this increased to 24 percent (an increase of 2 percentage points). However, people indicated they would only be willing to pay $1.15 for a 1 percent reduction in risk, where that reduction would still result in a moderate risk to human health (1 in 100 people could be at risk of infection). These results show that people will pay more for a better outcome. Overall, the estimates reveal that the highest marginal WTP was for good water clarity followed by good ecological quality.

4.6 Estimating the benefits of excluding stock from waterbodies

By combining the estimates of public preferences for water quality outcomes (Table 17) and estimates of the changes in *E. coli* concentrations that would occur as a result of excluding stock from waterways (outlined in Section 3), it was possible to assign monetary values to the reduced likelihood of people getting sick by excluding stock from waterways.

The lengths of the waterways (rivers and streams) that would be fenced under each stock exclusion option (in kilometres) were assigned a human health risk category based on the annual median and 95th percentile *E. coli* concentrations. To determine the effects of improvements in lake water quality, the length of the lake outlet reach was used as a proxy for the water quality of the whole lake. Outlet reaches are considered consistent with lake concentrations because they account for lake attenuation of contaminants like *E. coli*.

Lake outlet is the point where the lake flows out into a downstream river or stream.

Estimates of individual welfare values were aggregated up to the population level using an estimate of the 18-plus age population (3 197 916 people) from the 2013 New Zealand Census. This was multiplied by the proportion of the survey sample who were willing to pay for water quality improvements (79 percent). Table 18 presents estimates of the value of water quality improvements for each policy option by rivers, streams and lakes. Table 19 gives the total annual benefits for each stock exclusion option. Table 20 provides estimates of the present value of benefits over a 25-year horizon, discounted at 8 percent per annum. It shows the marginal benefits (the additional benefits resulting from excluding different types of stock) and the cumulative benefits over and above those already achieved through current or planned stock exclusion practices. For each table, the benefits are based on the most likely level of effectiveness of fencing for reducing *E. coli* concentrations in rivers, streams and lakes.

The results presented are based on percentage point reductions in human health risk between the status quo and all other options. They account for the degree of local and regional improvements specific to each territorial authority (TA). Improvements inside a TA are specified to be local to that population. Improvements outside a TA but within a region are specified to be regional to that TA's population. This was important to consider because improvements local to respondents are preferred over regional improvements, and regional improvements are preferred over those outside a respondent's region.

Table 17: Estimated willingness to pay for water quality outcomes

Water quality attribute	Outcome with management	Median willingness to pay for a percentage point increase in water quality outcomes (NZ$ 2015)
Human health risk	1 in 20 people will be at risk of infection (high risk)	$0.70 (0.22, 1.28)
	1 in 100 people will be at risk of infection (medium risk)	$1.15 (0.65, 1.65)
	1 in 1000 people will be at risk of infection (low risk)	$3.31 (2.79, 3.83)
Ecological quality	Moderate quality	$2.14 (1.73, 2.54)
	Good quality	$5.68 (5.41, 5.93)
Water clarity	Moderate clarity	$4.13 (3.64, 4.62)
	Good clarity	$7.39 (6.93, 7.86)

Note: 5th percentile and 95th percentile values are in brackets.

Table 18: Annual benefits for each stock exclusion policy option by waterbody type

Stock exclusion policy options			NZ$m 2015
1	Baseline: Current fencing, including regional council requirements to be implemented by July 2017	Streams	27
		Rivers	14.5
		Lakes	33.4
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	Streams	29.2
		Rivers	15.9
		Lakes	35.5
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	Streams	31.6
		Rivers	17.3
		Lakes	37.6
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	Streams	35.7
		Rivers	20.9
		Lakes	40.7
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	Streams	57.6
		Rivers	42
		Lakes	59.8
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	Streams	58.1
		Rivers	42.3
		Lakes	59.8
7	ALL Steep hill country option: exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	Streams	154.1
		Rivers	68.6
		Lakes	144.5

Table 19: Total annual benefits per stock exclusion policy option

Stock exclusion options		NZ$m 2015
1	Baseline: Current fencing, including regional council requirements to be implemented by July 2017	74.9
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	80.6
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	86.5
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	97.3
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	159.4
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	160.2
7	ALL Exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	367.2

Table 20: Present value of benefits of stock exclusion policy options (discounted at 8 percent over 25 years)

	Stock exclusion options	Marginal benefits (NZ$m)	Cumulative benefits (NZ$m)
1	Baseline: Current fencing, including regional council requirements to be implemented by July 2017	N/A	863.6
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	65.3	65.3
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	68.0	133.3
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	124.5	257.8
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	716.1	973.9
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	9.5	983.4
7	ALL Exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	2 386.4	3 369.8

The results show that excluding all dairy cattle from waterways would result in additional benefits, but on a much smaller scale, compared with those obtainable from current fencing practices. This is because most dairy farms already exclude their stock from waterways.

Excluding beef cattle would result in much larger benefits, with additional benefits of $716 million over 25 years, depending on how effectively fencing off stock reduces *E. coli* loads in streams, rivers and lakes. If deer are also excluded, additional benefits of $9.5 million could be achieved.

Excluding all dairy and beef cattle and deer from Accord and non-Accord streams into the hill country produces total benefits of $3.4 billion, above those already obtained from current stock exclusion practices.

Validity of results compared with similar studies

The WTP results are consistent with those of comparable choice experiment studies, which found significant public support for enhancing freshwater environments.

Miller and others (2015) estimated that Canterbury residents were willing to pay about $0.60 per 1 percent increase in the number of monitored sites suitable for swimming in the region. Their swimming quality classification concords with the 1:100 human health risk category used in this study (refer to Table 17). The estimated WTP of $1.15 for that category in this study was comparable with the results obtained by Miller and others (2015); while it is a higher value, it is consistent when considering the difference in scale between regional and national outcomes used across both studies.

Phillips (2014) provides another comparison with the estimates in this study of WTP for the 1:1000 human health risk category. Phillips estimated that Waikato residents were willing to pay about $2.00 per 1 percent increase in the proportion of monitored sites with less than one infection per 1000 swimmers. Again, the higher estimate of value in this study ($3.31) reflects the larger scale of national versus regional outcomes, while remaining comparable. The results in this study are also consistent with Phillips (2014) in finding that improvements in water clarity were valued higher compared with ecological quality or human health risk improvements.

Although these comparisons vary over research contexts and design elements, they do reveal that the WTP estimates found in this study are in the range of those found in comparable studies.

4.7 Summary

Non-market valuation provides a way of revealing what New Zealand residents are willing to pay for water quality improvements. In this study, a choice experiment approach was considered to be the most appropriate, where a survey of New Zealand residents was used to quantify the relative importance and WTP for improvements in water clarity, ecological quality and human health risk.

The individual marginal WTP results found in this study are consistent with those of comparable choice experiment studies, finding significant public support for enhancing the quality of freshwater environments.

The survey of New Zealand residents found that respondents are willing to pay the most for improvements in water clarity, followed by ecological quality. Improvements in the highest quality categories for each water quality outcome are preferred to increases in lower quality categories. Respondents prefer to have streams prioritised first, followed by lakes and then rivers. Improvements that are local to residents are preferred to regional improvements.

Excluding all dairy cattle from waterways would not result in substantial benefits in addition to current fencing levels and regional council requirements. This is because most dairy farms already exclude their stock from waterways.

Excluding beef cattle would result in much larger benefits, with additional benefits of $716 million over 25 years, depending on how effectively fencing off stock reduces *E. coli* loads in streams, rivers and lakes. Only small benefits will be achieved from fencing waterways on flat and rolling land on deer farms. This is because only an additional 260 kilometres of fencing would be required and the impact on *E. coli* in freshwater bodies is minimal compared with excluding dairy and beef cattle.

5 Cost and benefits of excluding stock from freshwater bodies

This section compares the costs of excluding stock from freshwater bodies with the benefits from a reduced risk of people getting sick from contact with fresh water in New Zealand. It follows the guidance set out in Treasury's guide to social cost–benefit analysis (New Zealand Treasury, 2015). Net benefits (benefits minus costs) and benefit–cost ratios are assessed to determine which stock exclusion approaches generate the greatest return in societal welfare.

The cost of fencing was estimated by AgriBusiness Group. Different fencing configurations were estimated based on various land use categories (for example, dairy, beef and deer) on different terrains (for example, flat or steep land) with low, medium and high cost options.

A unit price was generated for each type of fencing on a regional basis and aggregated to get a total cost of fencing for each policy option. Costs include installation and ongoing maintenance over a 25-year period, discounted at 8 percent. Both permanent and temporary fencing are included. Stock water reticulation costs also make up a significant proportion of total fencing costs.

Riparian planting costs are not included because approaches are highly varied across the country and tailored specifically to local conditions. Sufficient information was not available to accurately estimate riparian planting costs. The costs of stock crossings or of fencing other waterbodies, such as wetlands and drains, were also not included. Further detail on the cost estimation is set out in Section 2.

The benefits of a stock exclusion policy were estimated using data on peoples' willingness to pay for a reduction in the chances of getting sick from contact with freshwater bodies and estimates of the changes in *E. coli* concentrations that would occur from excluding stock from waterways. The willingness to pay information was generated by the Agribusiness and Economics Research Unit at Lincoln University using a survey of over 2000 New Zealand residents, and the changes in *E. coli* concentration were estimated by NIWA. The detailed methodology is set out in Sections 3 and 4.

The results of the survey showed that New Zealanders are willing to pay $3.31 for a percentage point increase in the number of waterways that have a low risk to human health. Estimates of individual willingness to pay were aggregated up to a population level using the 2013 New Zealand Census of the population aged 18 years and over.

5.1 Cost-benefit analysis

Table 21 presents the results of the cost–benefit analysis. The "medium" cost option is shown along with benefits based on the most likely effectiveness of fencing in reducing *E. coli* loads in waterways. Both the marginal costs (the additional costs and benefits incurred from a new stock exclusion policy) and cumulative costs (the accumulated costs of different policy options over and above current stock exclusion levels) are presented.

The marginal costs provide an indication of the relative costs and benefits of each stock exclusion policy option. The cumulative costs reflect the progressive nature of the policy options and quantify the additive or total cost and benefit as one policy option is implemented after another.

Main findings

Excluding dairy cattle on dairy platforms will cost $20 million over 25 years but will result in benefits of $65 million in terms of peoples' willingness to pay for a reduced risk to human health for all New Zealanders (or net benefits of $45 million). Excluding dairy cattle on dairy platforms would therefore achieve benefits of $3.20 for every dollar spent on fencing. The net benefits are in addition to what industry initiatives have achieved as of 2015, or the level of fencing that would occur if stock exclusion rules currently planned by regional councils were implemented successfully by July 2017.

Extending stock exclusion requirements to dairy cattle grazing on land owned by dairy farmers would result in additional costs of $1.4 million, with benefits valued at $68 million over 25 years (net benefits of $67 million). Excluding dairy cattle on land owned by third parties would result in additional costs of $10 million and additional benefits of $125 million over 25 years (with net benefits of $114 million). This results in cumulative net benefits of $226 million over and above current fencing levels if all dairy cattle are excluded (a benefit of $8.10 for every dollar spent on fencing).

Excluding beef cattle will also have a positive impact on water quality, but the costs are significantly higher than excluding only dairy cattle because a lot more fencing is required (additional costs of $327 million over 25 years). New Zealanders would be willing to pay $716 million to achieve the reductions in human health risks possible if beef cattle are excluded from waterways on flat and rolling land (net benefits of $390 million).

Excluding deer is estimated to cost only an additional $9 million because most deer farms already have fencing and only an additional 260 kilometres of fencing would be required. This would provide benefits of $10 million resulting in net benefits of $954 000 over 25 years.

Excluding all dairy and beef cattle and deer from Accord waterways on flat and rolling land is estimated to produce net benefits of $617 million (costs of $367 million and benefits of $983 million over 25 years).

Table 21: Present value of costs and benefits of stock exclusion policy options (over a 25-year period, discounted at 8 percent)

Option	Stock exclusion options	Marginal costs and benefits of excluding additional stock types from waterways			Cumulative costs and benefits of stock exclusion options			
		Additional cost (NZ$m)	Additional benefits (NZ$m)	Net marginal benefits (NZ$m)	Total cost (NZ$m)	Total benefits (NZ$m)	Total net benefits (NZ$m)	Benefit–cost ratio
1	Baseline: Current fencing, including regional council requirements, to be implemented by July 2017	N/A	N/A	N/A	7 875	864	–7 011	0.1
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	20	65	45	20	65	45	3.2
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	1	68	67	22	133	112	6.2
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	10	125	114	32	258	226	8.1
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	327	716	390	358	974	616	2.7
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	9	10	0.95	367	983	617	2.7
7	ALL Exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	1 069	2 386	1 317	1 436	3 370	1 934	2.3

Note: Costs are based on medium cost estimates; benefits are based on the most likely level of effectiveness of fencing at reducing *E. coli* loads in New Zealand waterways.

The table includes only the costs and benefits that could be quantified. Unquantified benefits from stock exclusion include improvements in water clarity and improvements in ecological health. Unquantified costs include the costs of riparian planting and management (because of the variability of riparian management practices) and monitoring and compliance.

Excluding dairy and beef cattle and deer from Accord and non-Accord streams into the hill country (slopes up to 28 degrees) will cost $1.4 million, compared with the current situation, and produce benefits of $3.4 billion (net benefits of $1.9 billion). The costs to be borne are significantly greater than focusing only on excluding dairy and beef cattle and deer from waterways on flat and rolling land, being an increase of $1 billion, compared with focusing only on flat and rolling land.

5.2 Limitations

The study only includes the benefits from reduced human health risks. Other benefits could not be quantified at this stage (including those of improved water clarity and ecosystem health). The actual benefits of stock exclusion are likely to be higher if these factors are taken into account, especially given that respondents in the survey placed a greater value on improvements in water clarity and ecosystem health compared with reductions in human health risk. The costs of riparian planting, stock crossings and fencing of other waterbodies, such as drains and wetlands, have also not been included.

Other limitations include:

- The costs of fencing may change over the 25-year horizon due to inflation (upward pressure) or increased competition (downward pressure).
- Likewise, public preferences for changes in water quality may change as a result of increased water scarcity and/or pollution.
- The choice of discount rate for private costs and public benefits can be contentious, with debate over the appropriate use of social discount rates and declining discount rates unresolved.
- The value of the next best use of cost expenditure is not able to be meaningfully assessed.
- The counterfactual water quality outcomes are uncertain over the time horizon of the costs–benefits stream.

6 Discussion

The national stock exclusion study assessed the costs and benefits associated with different stock exclusion options. The study has shown the effect different levels of fencing would have on *E. coli* concentrations in fresh water and the consequent changes in the levels of risk to human health. The study also estimated peoples' willingness to pay for improvements in water quality.

A significant proportion of New Zealand's waterways that could potentially be affected by stock access have already been fenced (67 000 kilometres of Accord waterways, as of 2015). Existing and proposed requirements set out by regional authorities will result in additional fencing to exclude more stock by July 2017. This will mean most dairy cattle will already be excluded from Accord waterways by 2017, and only 1379 kilometres of additional fencing will be required to effectively bar all dairy cattle from Accord waterways on flat and rolling land. Farmers would bear most of the stock exclusion costs, while the benefits associated with stock exclusion would accrue to all water users in New Zealand.

Introducing a national regulation for stock exclusion in New Zealand would be an effective way to help manage New Zealand's waterways by reducing the *E. coli* load from pastoral land uses to fresh water, thereby reducing the risk to human health. The cost–benefit analysis suggests the greatest benefit for every dollar spent on fencing will be achieved by focusing efforts on excluding all dairy cattle by 2025, with a return for all New Zealanders of $8.10 for every dollar spent on fencing.

To fence dairy cattle on dairy platforms from waterways would cost $20 million, discounted over 25 years, and produce benefits of $65 million (net benefits of $45 million). If stock exclusion is extended to all dairy cattle grazing on land owned by dairy farmers, costs would increase by $1.4 million and benefits would increase by an additional $68 million (with additional net benefits of $67 million). Including all dairy cattle grazing on land owned by a third party increases costs by $10 million and benefits by $125 million, producing additional net benefits of $114 million.

Excluding all dairy cattle results in total costs of $32 million and benefits of $258 million over and above current fencing levels. This results in net benefits of $226 million, producing $8.10 of benefit for every dollar spent on fencing.

To exclude beef cattle, farmers would need to fence 16 860 kilometres of waterways by 2030 at an additional cost of $327 million (discounted over 25 years). This would generate additional benefits of $716 million from reduced risks of people getting sick from contact with waterways, with additional net benefits of $390 million.

Fencing to exclude deer also returns a net benefit of $954 000. The costs of fencing deer are not as great as for beef cattle (an additional $9 million) because fewer streams need to be fenced (only 260 kilometres compared with 16 860 kilometres).

The total costs of fencing all dairy and beef cattle and deer from Accord and non-Accord streams into the hill country (slopes less than 28 degrees) is significant, at $1.4 billion. However, the benefits are even greater at $3.4 billion resulting in net benefits of $1.9 billion. This would result in over 70 000 kilometres of new fencing.

A big component of the costs of fencing waterways is the cost of reticulating stock drinking water. It is not known how many waterways are currently used by stock as drinking water. In a lot of cases, alternative water supplies may already be available, which would reduce the costs of the stock exclusion options. Further work is needed to quantify the extent of reticulation required. The costs of riparian planting have also not been quantified because of the variability that exists across the country.

This study did not quantify the benefits that would be gained from improvements in ecological quality and water clarity as a direct result of fencing to exclude stock (for example, from reduced stream bank erosion and sedimentation). Therefore, the estimates of benefits presented in this report are conservative and would likely be much higher if these other improvements were considered.

The New Zealand public is likely to place significant value on the water quality benefits arising from stock exclusion, as indicated in the survey of preferences for stock exclusion as a water resource management option. People are willing to pay the most for outcomes that result in good water clarity, followed by good ecological health. They are also willing to pay more for reductions in *E. coli* load that will reduce the risk to human health from a moderate or high level to a low level (1 in 1000 people at risk of infection from contact with fresh water).

6.1 Potential future work

Several projects could potentially build on this study in the near future. They include:

- developing a more accurate method for estimating the costs to supply reticulated alternative stock drinking water, and accounting for spatial variability particularly at the farm scale;
- assessing the effectiveness of riparian buffers in reducing contaminant loads to fresh water and the costs of planting and on-going management. Efforts should be made to coordinate with different research groups and combine resources;
- assessing the costs of stock crossings and of fencing other waterbodies, such as drains and wetlands;
- devising a method of assessing stock numbers (and farm productivity and profitability) in conjunction with land use data, to assess the impact of policies on farm performance. This work could also help to develop a more in-depth understanding of the effects of such regulations on the national economy.

Appendix 1: Length of non-Accord and Accord streams

Table 22: Length (kilometres) of non-Accord and Accord streams grouped by slope class in each super region and region

Super region and region	Non-Accord streams				Accord streams				Regional total
	<16°	16 to 28°	>28°	Total	<16°	16 to 28°	>28°	Total	
Northern North Island	17 469	3 687	233	21 389	57 853	14 224	2 954	75 030	96 419
Auckland	2 072	208	6	2 285	3 974	310	8	4 292	6 577
Bay of Plenty	1 982	818	181	2 981	9 544	4 008	2 312	15 864	18 845
Gisborne	1 499	983	9	2 491	5 549	4 195	410	10 154	12 646
Northland	4 215	500	4	4 719	12 538	1 144	17	13 699	18 418
Waikato	7 701	1 178	33	8 912	26 248	4 566	208	31 021	39 933
Southern North Island	14 888	6 341	289	21 518	39 567	19 637	2 029	61 234	82 752
Hawke's Bay	5 661	1 315	147	7 122	12 210	4 781	652	17 644	24 766
Manawatū–Whanganui	6 600	3 072	96	9 768	17 191	7 962	606	25 758	35 526
Taranaki	1 372	1 295	7	2 675	6 686	4 205	71	10 963	13 637
Wellington	1 254	660	40	1 953	3 480	2 689	701	6 869	8 823
South Island	33 440	13 515	3 354	50 309	80 464	50 345	39 801	170 609	220 919
Canterbury	11 515	4 976	1 212	17 703	24 372	12 114	7 859	44 345	62 048
Canterbury and Otago	2 646	1 309	185	4 140	3 447	2 304	839	6 590	10 730
Marlborough	815	1 980	870	3 665	2 987	5 369	3 003	11 359	15 024
Otago	11 359	3 101	664	15 124	15 628	7 442	5 012	28 082	43 206
Southland	6 221	1 256	243	7 719	17 268	7 322	8 828	33 419	41 138
Tasman	769	833	168	1 770	3 684	5 573	3 111	12 368	14 138
West Coast	115	60	13	188	13 079	10 221	11 148	34 447	34 635
National total	65 796	23 543	3 877	93 216	177 884	842 06	44 784	306 874	400 090

Appendix 2: National Objective Framework *E. coli* attribute

Table 23: National Objectives Framework attribute table for *E. coli*

<table>
<tr><td colspan="2">Value</td><td colspan="2">Human health for recreation</td></tr>
<tr><td colspan="2">Freshwater body type</td><td colspan="2">Lakes and rivers</td></tr>
<tr><td colspan="2">Attribute</td><td colspan="2">E. coli</td></tr>
<tr><td colspan="2">Attribute unit</td><td colspan="2">E. coli /100ml (number of E. coli per hundred millilitres)</td></tr>
<tr><th>Attribute state</th><th>Numeric attribute state</th><th>Sampling statistic</th><th>Narrative attribute state</th></tr>
<tr><td rowspan="2">A</td><td rowspan="2">≤260</td><td>Annual median</td><td>People are exposed to a very low risk of infection (less than 0.1 percent risk) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).</td></tr>
<tr><td>95th percentile</td><td>People are exposed to a low risk of infection (up to 1 percent risk) when undertaking activities likely to involve full immersion.</td></tr>
<tr><td rowspan="2">B</td><td rowspan="2">>260 and ≤540</td><td>Annual median</td><td>People are exposed to a low risk of infection (less than 1 percent risk) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).</td></tr>
<tr><td>95th percentile</td><td>People are exposed to a moderate risk of infection (less than 5 percent risk) when undertaking activities likely to involve full immersion. The minimum acceptable state is 540 per 100ml for activities likely to involve full immersion.</td></tr>
<tr><td>C</td><td>>540 and ≤1000</td><td>Annual median</td><td rowspan="2">People are exposed to a moderate risk of infection (less than 5 percent risk) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating). People are exposed to a high risk of infection (greater than 5 percent risk) from contact with water during activities likely to involve immersion.</td></tr>
<tr><td>National bottom line</td><td>1000</td><td>Annual median</td></tr>
<tr><td>D</td><td>>1000</td><td>Annual median</td><td>People are exposed to a high risk of infection (greater than 5 percent risk) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).</td></tr>
</table>

Reproduced from Appendix 2 of the *National Policy Statement for Freshwater Management* (Ministry for the Environment, 2014).

Appendix 3: Information and assumptions used to develop the stock exclusion options

Table 24: Information and assumptions for each stock exclusion option

Option	Policy options: stock to be excluded	Information required	Modelling assumptions
1a	Baseline: Current level of fencing to exclude stock	Current level of fencing estimated using the preliminary results of the 2015 Survey of Rural Decision Makers conducted by Landcare Research (as of October 2015) (Brown, 2015). Waterways were identified and mapped using the River Environment Classification (Version 2) (REC2).	Fencing was assumed to apply only to waterways meeting the definition within the Sustainable Dairying Water Accord (Accord waterways) of >1 metre wide, >30 centimetres deep, and permanently flowing.
1b	Baseline: Current level of fencing to exclude stock, plus regional council requirements to be implemented by July 2017	Incorporates regional policies identified by the Land and Water Forum in a desktop review, and verified via phone conversations with regional staff. Descriptions of these policies are provided in Appendix 4. Only stock exclusion practices for those regions that already have specific stock exclusion policies, or are planning policy changes before July 2017, were included for this scenario.	Stock exclusion policies will be fully implemented as described by each regional council before July 2017. In regions with priority waterways or zones, such as Waikato, stock exclusion was applied to those waterways only, while the remainder of waterways within that region were assigned the current level of fencing (as per option 1a).
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	Dairy platforms identified using a combination of FarmsOnline and Land Cover Database Version 4 (LCDB4) data.	Applied to Accord waterways on land with an average slope of less than 16 degrees.
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	Pastoral land use classes derived from FarmsOnline were further split on the basis of unpublished preliminary data from the 2015 Agricultural Production Survey (APS) undertaken by Statistics New Zealand. The Ministry for Primary Industries provided APS data aggregated by super region, and the data were analysed by AgResearch.	Split dairy platform and dairy run-off (grazing on land owned by dairy farmers) based on the ratio of cows and heifers in milk to dairy cattle not in milk (from APS data).
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	The proportion of dairy cattle grazing on land owned by a third party was calculated using the 2015 APS data (as for option 3).	Dairy cattle grazing on land owned by a third party were assumed to be represented by "non-milking dairy cattle" recorded on sheep and beef farms within the APS.
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	The proportion of land used for farming beef cattle was identified using a combination of FarmsOnline and LCDB4 data.	Sheep and beef farms identified in land use data provided the best representation of the location of beef cattle in New Zealand.
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	The proportion of land used for farming deer was identified using a combination of FarmsOnline and LCDB4 data.	No additional assumptions.
7	All Exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	Slope of land was calculated using a Digital Elevation Model with 20 metre contours.	Includes all streams within REC2, both Accord and non-Accord (i.e., smaller and larger waterways, not necessarily permanently flowing).

Appendix 4: Existing or planned regional fencing policies by region

Table 25: Existing or planned regional fencing policies by region

Regional authority	Plan document or source	Applicable requirements for stock exclusion
Auckland Council	Auckland Draft Unitary Plan (2013)	Proposes exclusion of all stock on intensively farmed land from any lakes, rivers, streams or wetlands, with the exception of intermittent streams, within five years of notification. Intermittent streams must have stock exclusion within 10 years of notification. Stock exclusion can be achieved using fences or riparian planting.
Waikato Regional Council	In preparation	The Land and Water Forum (LAWF) (2015) reports that all stock is to be excluded from Priority One waterways in the Waikato. However, this policy is not yet in place, and the Waikato Regional Council Collaborative Stakeholder Group is currently assessing various mitigation options including stock exclusion as part of the preparation of a new regional plan.
Hawke's Bay Regional Council	Hawke's Bay Resource Management Plan (2014) Tukituki River Catchment Plan (2015)	Hawke's Bay has no region-wide policy on stock exclusion. Instead, rules will be proposed on a catchment-by-catchment basis (pers comm, Barry Lynch, Hawke's Bay Regional Council). The Tukituki River is the first catchment with a specific stock exclusion plan, this requires stock exclusion along all waterways (lakes, wetlands and rivers whether they are intermittent or permanently flowing) for all stock, with the exception of sheep, on land with a slope of less than 15 degrees.
Gisborne District Council	Proposed Gisborne Regional Freshwater Plan (2015)	According to the LAWF (2015), no geographically specific plans exist for stock exclusion under the proposed plan, however, exclusion will be required for new intensive farms.
Taranaki Regional Council	Draft update to the Regional Freshwater Plan (2001)	More restrictive fencing and riparian management regulations are proposed in some parts of Taranaki under the plan. Intensively farmed stock to be excluded from all waterways on the ring plain and on northern and southern coastal terraces (pers comm, Chris Spurdle). Further restrictions that have not yet been specified will be required for waterways of outstanding natural value (i.e., the Stony and Maketawa catchments and Lake Rotokare). Other stock (sheep, deer, pigs) are not included in the proposed policy.
Greater Wellington Regional Council	Proposed Natural Resources Plan for Wellington (2015)	Proposes a two-stage policy for stock exclusion. Phase one would require fencing along all priority sites including significant wetlands, near water supply intakes and fish and bird habitats within three years of notification. Phase two would exclude all stock, except sheep, on waterways wider than 1 metre on lowland properties and wider than 3 metres on hill country within seven years of notification.
Marlborough	Resource planning documents in Marlborough are currently under review	According to the LAWF (2015), it is proposed that all stock other than sheep and beef cattle be prohibited from entering or passing across the bed of any river or lake. Intensively farmed beef cattle may also be excluded.
Environment Canterbury	Canterbury Natural Resources Regional Plan (2011)	All intensively farmed stock to be prohibited from entering any natural waterway. Additionally, cattle, farmed deer or pigs prohibited from entering water ways within 1 kilometre of a bathing site, drinking water supply intake, salmon or inanga spawning site or within permanently flowing reaches of specified rivers.

Source: Land and Water Forum, 2015b.

Appendix 5: Fencing costs by region

Table 26: Regional labour costs (per metre) for five fence types over flat, rolling and steep terrain in New Zealand

Labour costs for 1 metre of fencing (NZ$)	Fencing to exclude sheep and/or cattle									Fencing to exclude cattle only			Fencing to exclude deer		
	Non-electric 8 wire			Non-electric netting			Electric 4 wire			Electric 2 wire			Non-electric netting		
	Flat	Rolling	Steep	Flat	Rolling	Steep	Flat	Rolling	Steep	Flat	Rolling	Steep	Flat	Rolling	Steep
Northland	7.2	7.3	10.7	7.2	7.3	10.3	4.5	4.5	5.8	3.3	3.3	4.7	8.5	9.0	12.7
Auckland	9.7	10.0	16.2	9.3	9.7	18.0	5.3	5.7	8.0	3.5	3.5	5.7	12.2	12.8	19.5
Waikato	8.0	8.9	9.8	6.9	7.8	9.0	3.9	4.5	5.1	2.8	9.9	3.7	10.5	11.1	12.5
Bay of Plenty	6.8	7.2	9.5	6.6	6.9	9.3	3.4	3.4	4.3	2.2	2.2	2.8	8.2	8.2	10.5
Gisborne	8.8	8.8	11.0	8.7	8.7	11.0	5.5	5.7	6.7	3.5	3.5	4.3	12.5	12.5	15.0
Hawke's Bay	8.2	9.2	13.0	7.7	8.0	11.4	5.1	5.4	8.7	3.3	3.3	5.4	10.5	10.8	15.1
Taranaki	7.5	8.3	10.3	6.8	7.7	9.9	3.7	3.8	5.7	2.7	2.8	4.0	11.0	13.5	17.0
Horizons (Manawatū-Whanganui)	6.8	8.0	11.0	6.7	7.8	10.8	3.6	4.0	5.2	2.8	3.2	4.2	7.3	8.3	10.7
Greater Wellington	8.2	9.3	13.5	8.4	9.7	13.6	6.3	6.8	8.2	4.7	5.5	6.6	10.3	12.0	16.9
Marlborough	7.2	7.6	10.3	6.4	7.0	10.0	3.8	4.0	5.2	2.5	2.5	3.3	7.3	8.8	10.5
West Coast	9.0	9.5	12.7	9.0	9.5	12.7	2.9	3.5	5.5	3.5	3.5	4.7	9.0	9.5	12.7
Canterbury	4.5	5.1	7.4	4.8	5.8	9.1	2.9	3.5	5.5	1.5	1.7	2.3	5.0	6.0	9.5
Otago	7.2	7.6	10.7	6.0	6.7	10.5	3.7	4.5	6.4	2.4	3.4	4.9	10.0	10.9	14.8
Southland	4.3	4.5	6.0	3.9	4.0	6.0	2.3	2.3	3.6	1.8	1.8	2.8	5.8	5.9	9.2

Table 27: Regional material costs (per metre) for five fence types over flat, rolling and steep terrain in New Zealand

Total material costs for 1 metre of fencing (NZ$)	Sheep and cattle non-electric 8 wire	Sheep and cattle non-electric netting	Sheep and cattle electric 4 wire	Cattle electric 2 wire	Non-electric deer netting
Northland	5.2	4.9	2.2	1.6	9.1
Auckland	5.4	4.8	2.2	1.6	9.2
Waikato	5.6	5.1	2.3	1.7	9.2
Bay of Plenty	5.6	5	2.3	1.7	9.2
Gisborne	5.6	5	2.3	1.7	9.2
Hawke's Bay	5.4	4.8	2.2	1.6	8.9
Taranaki	5.4	4.8	2.2	1.6	8.9
Horizons (Manawatū-Whanganui)	5.4	4.8	2.2	1.6	8.9
Greater Wellington	5.4	4.8	2.2	1.6	8.9
Marlborough	6.1	5.4	2.5	1.8	10.4
West Coast	6.1	5.4	2.5	1.8	10.4
Canterbury	6.6	5.8	2.6	1.9	10.5
Otago	5.7	5.1	2.3	1.7	9.8
Southland	5.9	5.3	2.4	1.8	9.7

Table 28: Regional fencing costs (per metre) for five fence types over flat, rolling and steep terrain in New Zealand (labour and materials)

Total cost for one metre of fencing (NZ$)	Fencing to exclude sheep and/or cattle									Fencing to exclude cattle only			Fencing to exclude deer		
	Non-electric 8 wire			Non-electric netting			Electric 4 wire			Electric 2 wire			Non-electric netting		
	Flat	Rolling	Steep	Flat	Rolling	Steep	Flat	Rolling	Steep	Flat	Rolling	Steep	Flat	Rolling	Steep
Northland	12.3	12.5	15.8	12.0	12.2	15.2	6.7	6.7	8.1	4.9	4.9	6.3	17.6	18.1	21.7
Auckland	15.0	15.4	21.5	14.1	14.5	22.8	7.5	7.9	10.2	5.1	5.1	7.3	21.3	22.0	28.6
Waikato	13.6	14.5	15.4	12.0	12.8	14.1	6.2	6.8	7.4	4.4	11.5	5.3	19.7	20.4	21.8
Bay of Plenty	12.4	12.8	15.1	11.6	12.0	14.3	5.7	5.7	6.5	3.8	3.8	4.5	17.4	17.4	19.7
Gisborne	14.4	14.4	16.6	13.7	13.7	16.0	7.8	8.0	9.0	5.2	5.2	6.0	21.7	21.7	24.2
Hawke's Bay	13.5	14.5	18.4	12.5	12.8	16.2	7.3	7.6	10.9	4.9	4.9	7.0	19.4	19.8	24.0
Taranaki	12.9	13.7	15.7	11.7	12.5	14.8	5.9	6.0	7.9	4.2	4.4	5.6	19.9	22.4	25.9
Horizons (Manawatū-Whanganui)	12.2	13.4	16.4	11.5	12.7	15.7	5.8	6.2	7.4	4.4	4.7	5.7	16.3	17.3	19.6
Greater Wellington	13.5	14.7	19.0	13.2	14.5	18.5	8.5	9.0	10.5	6.2	7.1	8.2	19.3	20.9	26.0
Marlborough	13.3	13.7	16.5	11.8	12.4	15.4	6.3	6.5	7.6	4.3	4.3	5.1	17.6	19.1	20.9
West Coast	15.1	15.6	18.9	14.4	14.9	18.2	5.4	6.0	7.9	5.3	5.3	6.5	19.4	19.9	23.1
Canterbury	11.1	11.7	14.0	10.5	11.5	15.0	5.5	6.1	8.0	3.4	3.6	4.2	15.5	16.5	19.9
Otago	12.8	13.2	16.3	11.1	11.7	15.6	6.0	6.8	8.7	4.1	5.0	6.6	19.8	20.7	24.6
Southland	10.2	10.4	11.9	9.2	9.3	11.3	4.7	4.7	6.0	3.6	3.6	4.6	15.5	15.6	18.9

Appendix 6: Changes in *E. coli* National Objective Framework bands for each stock exclusion option

Table 29: Changes in *E. coli* bands for primary contact recreation (95th percentile) for excluding stock from Accord waterways

#	Options	Low effectiveness (%)			Most likely effectiveness (%)			High effectiveness (%)		
		A Band	B Band	Below standard	A Band	B Band	Below standard	A Band	B Band	Below standard
1a	Baseline: Current level of fencing to exclude stock	46.98	8.38	44.55	47.66	8.93	43.41	48.30	9.48	42.23
1b	Baseline: Current level of fencing to exclude stock, plus regional council requirements to be implemented by July 2017	47.03	8.42	44.56	47.96	9.41	42.62	48.94	11.03	40.03
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	47.03	8.42	44.55	47.99	9.43	42.57	49.05	11.05	39.90
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	47.03	8.42	44.55	47.99	9.44	42.57	49.06	11.06	39.87
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	47.03	8.42	44.55	48.00	9.45	42.54	49.09	11.07	39.83
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	47.08	8.47	44.46	48.32	9.69	41.99	49.72	11.78	38.51
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	47.08	8.47	44.44	48.33	9.69	41.98	49.76	11.80	38.44

Table 30: Changes in *E. coli* bands for primary contact recreation (95th percentile) if all dairy and beef cattle and deer are excluded into the hill country (slopes up to 28 degrees) for both Accord and non-Accord waterways

#	Option	Low effectiveness (%)			Most likely effectiveness (%)			High effectiveness (%)		
		A Band	B Band	Below standard	A Band	B Band	Below standard	A Band	B Band	Below standard
	ACCORD WATERWAYS									
1	Baseline: Current level of fencing to exclude stock, plus regional council requirements to be implemented by July 2017	47.03	8.42	44.56	47.96	9.41	42.62	48.94	11.03	40.03
7	Exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	47.35	8.60	44.05	49.99	10.41	39.60	53.08	15.01	31.91
	NON-ACCORD WATERWAYS									
1	Baseline: Current level of fencing to exclude stock, plus regional council requirements to be implemented by July 2017	29.61	7.49	62.90	29.71	8.71	61.58	30.09	10.74	59.17
7	Exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	30.07	7.73	62.20	32.39	12.41	55.20	36.77	22.41	40.82

Table 31: Changes in *E. coli* bands for secondary contact recreation (annual median concentration) for excluding stock from Accord waterways

#	Option	Low effectiveness (%)				Most likely effectiveness (%)				High effectiveness (%)			
		A Band	B Band	C Band	D Band	A Band	B Band	C Band	D Band	A Band	B Band	C Band	D Band
1a	Baseline: Current level of fencing to exclude stock	84.21	14.61	1.16	0.03	90.38	9.37	0.24	0.01	93.51	6.33	0.16	0.00
1b	Baseline: Current level of fencing to exclude stock, plus regional council requirements to be implemented by July 2017	84.44	14.40	1.13	0.03	91.35	8.41	0.23	0.00	94.22	5.63	0.15	0.00
2	Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	84.46	14.41	1.11	0.03	91.51	8.26	0.22	0.00	94.37	5.49	0.14	0.00
3	Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	84.46	14.41	1.10	0.03	91.53	8.25	0.22	0.00	94.38	5.48	0.14	0.00
4	Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	84.48	14.40	1.09	0.03	91.70	8.08	0.22	0.00	94.59	5.27	0.14	0.00
5	Option 4 plus: Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	84.86	14.07	1.05	0.03	93.37	6.42	0.20	0.00	96.07	3.80	0.13	0.00
6	Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	83.23	15.56	1.18	0.03	93.41	6.38	0.20	0.00	96.10	3.77	0.13	0.00

Table 32: Changes in *E. coli* bands for secondary contact recreation (annual median concentration) if all dairy and beef cattle and deer are excluded into the hill country (slopes up to 28 degrees) for both Accord and non-Accord waterways

#	Option	Low effectiveness (%)				Most likely effectiveness (%)				High effectiveness (%)			
		A Band	B Band	C Band	D Band	A Band	B Band	C Band	D Band	A Band	B Band	C Band	D Band
ACCORD WATERWAYS													
1	Baseline: Current level of fencing to exclude stock, plus regional council requirements to be implemented by July 2017	84.44	14.40	1.13	0.03	91.35	8.41	0.23	0.00	94.22	5.63	0.15	0.00
7	Exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	85.61	13.45	0.93	0.02	97.01	2.88	0.11	0.00	98.81	1.12	0.08	0.00
NON-ACCORD WATERWAYS													
1	Baseline: Current level of fencing to exclude stock, plus regional council requirements to be implemented by July 2017	81.90	17.87	0.23	0.00	82.83	16.94	0.22	0.00	82.90	16.88	0.22	0.00
7	Exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	86.35	13.52	0.13	0.00	97.11	2.81	0.08	0.00	97.70	2.22	0.08	0.00

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